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PROBLEMS OF PREPARATION FOR MEDICAL COLLEGE

A symposium on "Problems of Preparation for Medical College" presented as part of the program of the Medical Sciences Section at the annual meeting of The Ohio Academy of Science held at Wittenberg College, Springfield, Ohio, April 20, 1956.

Chairman: RALPH W. STACY.

Participants: T. K. MARKOPOULOS, President, Ohio Chapter, *Alpha Epsilon Delta*, Premedical National Honorary Fraternity; RICHARD L. MEILING, Associate Dean, College of Medicine, Ohio State University; RALPH W. STACY, Executive Vice-President, Medical Section, Ohio Academy of Science; JAY JACOBY, Professor of Anesthesiology, Ohio State University; R. A. HEFNER, Chairman, Department of Zoology, Miami University.

Symposium Editor: RALPH W. STACY.

INTRODUCTION

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In the past several years, those of us who are concerned with the training of physicians have become increasingly aware of the existence of deficiencies in such training. There are large areas in which our doctors are not proficient and in which they should be adequately trained. So far as has been possible, the medical faculties have attempted to fill these gaps, but their ability to do so turns out to be limited because of the notoriously full curriculum of the medical student. No one is willing to delete classical and standard medical information in order to insert more modern information.

We will learn later that much of this missing information is material which many of us consider should have been learned in premedical training. However, there is an increasing tendency to delete technical material from the premedical curriculum and substitute material which is supposed to provide a fuller, more cultural life. It is postulated that the need for more rigorous technical training and the desire for more extensive cultural training are not completely compatible.

Thus, we are faced with a problem which can be solved only by mutual agreement between those of us who are directly concerned with medical education, and those of us from the arts and sciences colleges who are involved in training of students in premedical curricula. This is a national problem, but unfortunately there are no major national organizations encompassing both groups. The Ohio Academy of Science, on the other hand, presents a unique opportunity for intercourse of these two groups.

It is our hope that in this symposium, we will fracture the crust of our mutual problems and will make a beginning toward arriving at an understanding of what

is needed and how to proceed in administering to these needs. Let us hope that in this first session, we will at least get to know each other more intimately. We cannot hope to solve the problem in one session; such problems as these are solved by months and years of endeavor. However, we are given the chance to start, and in the way of men interested in advancement of activities of the human race, we will begin and continue.

We would like to express our appreciation to Dr. Ralph Dexter, the secretary of the society, for his cooperation in setting up the symposium, and for his suggestion that the symposium be published in its entirety in THE OHIO JOURNAL OF SCIENCE so that its message will reach more persons than can gather here.

HIGHLIGHTS OF THE PREMEDICAL STUDENT'S PROBLEMS

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The problems of a premedical student may be divided into 9 parts as follows: 1. problem of a balanced education, 2. problem of the classroom, 3. problem of grades, 4. problem of study habits, 5. problem of admittance to medical school, 6. problem of adviser and advising, 7. problem of marriage, 8. problem of finance, and 9. problem of draft.

1. The problem of a balanced education. Many students feel they should obtain a liberal preprofessional education so that the student's attitude of mind would be reflected towards social values and the willingness to change attitudes with the growth and development of the country. It should stimulate curiosity and a desire to develop new ideas and to look into new fields. In brief, the student should be stimulated to think as well as learn.

However, what actually happens is that the undergraduate student takes his science requirements and instead of stopping there, as far as science courses are concerned, feels that he is obliged to major in a science in order to obtain admission to medical school.

This is probably due to many reasons, such as the poor advice from a freshman in medical school or from a well-meaning family physician, or the advice of an aggressive premedical adviser who insists that additional courses give the student advantages toward admittance, or to lighten the burden of the freshman medical courses. Therefore, most of the premedical students feel that these added courses in science do enhance their chances in selection to a medical school.

2. The problem of the classroom. Another problem to the student is the overcrowded classrooms. The teacher to student ratio is very low. In this situation it is easy for a minority of highly ambitious students to monopolize the classroom.

3. The problem of grades. Competition is so "keen" for grades that in the third and fourth year the students are so "hepped up" for grades that they work toward the grade and not the knowledge. As a result of this, the students do not benefit as much as they should from their courses.

4. The problem of study habits. The improper study habits and the improper academic approach toward a subject create other problems for the student since it is frequently the amount of work rather than the difficulty of the work which causes the trouble.

One of the major deficiencies of most premedical students is poor reading ability. This can be easily corrected early in the college career.

One way of correcting this is by the use of correct English in all courses. The present day trend towards the use of objective examination technics places little stress on this qualification. The ability of expression is a highly desirable talent in the medical profession, or any profession for that matter.

5. Problem of admittance to medical school. Still another problem is the undue

delay in notification of acceptance or rejection from a medical school. It produces an emotional strain which in many students interferes with their school work. Probably one way of solving this situation is to have a uniform date for filing applications and a uniform date in releasing the acceptances.

6. *Problem of adviser and advising.* The difficulty in seeing an adviser and the inadequate number of advisers available to the large number of students pose another problem.

Colleges should give more attention to their advisory program by giving the advisers lighter teaching loads so they can devote more time to students. They should provide travel funds to permit visits to professional schools, as well as participation in conferences and regional meetings pertaining to educational problems.

7. *The problem of marriage.* Many students are faced with the problem of whether or not they should marry before or after they enter medical school. Most believe the best solution to this is before entrance, whereby the wife (or husband, whatever the case may be) helps support the spouse through school; however, the bearing of a child to a couple becomes a financial worry and an emotional strain is placed on the student involved.

8. *The problem of finance.* This is a big problem prior to entrance in medical school; however, it is usually "ironed out" before the student enters professional school.

9. *The problem of the draft.* This is probably one of the least of worries for the student since he is exempt until his completion of medical school.

These have been most of the problems which affect premedical students. The solving of these will help in the development of the student as a citizen since his profession is practiced in a social and economic environment.

PROBLEMS OF PREPARATION FOR MEDICAL COLLEGE
THE VIEWPOINT OF A MEDICAL COLLEGE ADMINISTRATOR

RICHARD L. MEILING, M.D.
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The subject of our symposium today; namely, "Problems of Preparation for Medical College," has received in recent years increasing attention from prospective medical students, their parents, high school and college science faculty members, medical college entrance committees, medical college faculty members, practicing physicians, and the lay public (including the educators, press, social workers, and patients). The interest of this large and diversified group is in geometric proportion to the public and professional reputations and interests of the personalities, the institutions, and the organizations involved. I full well recognize the controversial aspects of any remarks I may now make and hasten to assure you they are my personal opinions and not necessarily the policy of our University.

As a medical educator and administrator, but still, first and foremost, a physician dedicated to the "art of the practice of medicine," I find but one single logical approach to the problem of preparation for medical school—Why do we have medical schools? Perhaps, stated in a slightly different manner—What is the goal of a medical education? If we can answer this question then the problems of preparation for entrance to medical school should also be solvable.

I believe the goal of a medical education is to train the individual to be a physician to serve the health needs of the people.

You will note I have not included the training of medical specialists in either the basic medical sciences or the clinical medical areas, nor have I included the

development of medical research investigators, nor the training of a medical faculty. This is neither the time nor place for the discussion of these problems; but permit me to state in passing that the University Graduate School faculty is available for the education of basic medical scientists, and the research laboratories and foundations are equipped to develop medical research investigators while our teaching hospitals are responsible for the postgraduate medical training in accordance with the requirements of the medical specialty boards and colleges. From these several sources of postgraduate medical education should then come our future medical faculty members.

Assuming that for the development of my thesis you accept my basic proposition as to the goal of medical education, then let us turn to the preparation of the student who is to voluntarily select the career of a physician as his life work.

The student must have personal motivation to enter medicine, a devotion to study and learning, and a curiosity which will inspire personal investigation. His preparatory education must provide training to understand basic problems, for as a physician he must realize the limits of medical knowledge and strive to understand the methods and efforts required to expand these limits to the benefit of the patient. This sense of responsibility for the patient must be developed early, for associated with fundamental knowledge and experience it should be the basic characteristic of our physician. I do not believe preceptors, advisers or councilors are necessary, helpful, or required for our student during his medical education if our student is to have the prerequisite maturity of a physician and be intrusted with the care of patients upon graduation.

The academic preparation of our prospective student, therefore, should be centered upon disciplined self-development with broad interests rather than an early narrowing of his field to the areas of biology, chemistry, physics, and such subjects as psychology, genetics, statistics, and sociology.

It is true our prospective student needs a "working knowledge" of chemistry, physics, and biology but it is only fair to ask the question, "Why must the physician spend unlimited hours in lecture and laboratory work, first in high school, then in college, and again in medical school (and if he elects to specialize, then still further courses in the postgraduate specialty training) in the fields of chemistry, physics, and biology?" Why do premedical advisers urge college students to fill their curriculum with courses in physical chemistry, agricultural chemistry, physiological chemistry, etc.?

In my opinion, the students who elect medicine as a career are not so poor that they require all this multiplicity of science courses to obtain broad fundamentals. Nor do I believe our faculties are so inept in presentation that the student must be plagued year after year with a spiraling group of science courses so that he may enter medical school. Could it be that our science faculty is more interested in developing science students rather than prospective physicians? I am certain that as the clinical subjects in medical schools require more time for presentation and thus force their way into the available hours of the sophomore and even the freshman year, science for science sake will be limited in the medical curriculum with more emphasis on scientific "working knowledge" rather than specific scientific specialization.

I trust that in our American colleges, education in the areas of history, language, culture, philosophy, economics, politics, ethics, and religion will be available to the prospective medical student, but not as "required courses" for graduation. The only justification of a four-year college education for the preparation of medical studies I believe to be the development of a student capable of understanding community life and society in which he and his patients-to-be must live. Our European and English colleagues who go directly from preparatory school to the University for five and one-half years of medical training are our equals in the scientific approach to medicine. If your nationalistic provincialism has been

touched by such a remark, then ask yourself who it was that gave us the antibiotics, the sulfonamides, the roentgen and radiological therapy, the vitamins and several of the hormones. They were not products of our American educational system. Surprising what those medical men have done with a total of one year of physics and one year of chemistry as a "working knowledge of science" prior to entering the clinical years of their medical studies in their Universities. Still more surprising that the English and Northern European medical students have not been exposed to a system of designated advisers and councilors, or required courses, but have sought out advice as they have sought knowledge, by independent decision and action.

The advancement of medical knowledge and development of health facilities in this the atomic age permits one physician to care for more and more patients—but the physician must be an individual of broad interests, dedicated motivation and a continuing investigative urge if his patients are to receive the most modern treatment available.

Hours, days, weeks, and years spent with formulas, equations, complex reactions, dissections, and theories ad quantum are not, per se, the indicators of the knowledge we seek in the student of today, to be the physician of tomorrow. Rather, we hope to find a student willing to dedicate himself to a medical career because he is motivated to seek the best treatment for his patients of tomorrow.

Does this mean dropping from our so-called "premedical education" organic chemistry, physics, or embryology? Decidedly not, but it should mean the coordination of these basic sciences with a broad insight into the problems of total man and his environment, to be obtained by a proper balance in curriculum and extra-curricular activities.

To summarize my thoughts then as to the preparation for medical education, I should be so bold as to suggest the dropping of the term "premedical studies." Rather, I should hope our medical student would come to our medical faculty with his mind developed through college education that he may think; with his hands trained that he may apply the scientific and mechanical tools of the health sciences, and his heart dedicated to human understanding and sympathy for his fellow man. Such a student then, with these three attributes of his mind, his hands, and his heart, will be the practitioner of the "art of the practice of medicine" and will bring relief to his patients afflicted with mental and physical disease, pain, and suffering.

PREPARATION FOR THE PRECLINICAL YEARS OF MEDICAL COLLEGE

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The preclinical years of medicine are in general the first two years. During this time the student receives instruction in what are known as the "basic sciences" of medicine, including anatomy, biochemistry, physiology, pathology, and bacteriology, and related courses. These are the courses which contain information on the nature and function of the body parts and the whole body, and on the basic processes which occur in disease. It is on this information that all of the techniques and procedures of the following clinical years are based. These courses provide the foundation for the training of the physician, and if the foundation structure is found wanting, the physician will be found wanting.

There are several reasons why medicine of today is not, or should not be, the same as it was ten or twenty years ago. Chief among these are (1) that during

the past several decades, information about all bodily processes has been accumulating at a prodigious rate, resulting in the condition that nowadays there is never any question about what one can find to put into a course, but rather what can be thrown out with the least harm, and (2) the fact that other sciences are contributing greatly to the understanding of physiological and pathological processes. Inherent in this second reason for change is the natural evolution of any science. The sequence of development of a science runs (a) qualitative observations, (b) qualitative experimental observations, and (c) quantitative experimental observations. Medicine is just making the transition from (b) to (c).

These changes in the general nature of the field of medicine are the result of efforts of a large number of scientists, many of whom are the professors who teach the medical students. As a result, the staff of a medical college is usually well equipped to present the modern material to the students, but cannot do so because of the time requirements of the existing medical curriculum. There ensues from this unfortunate set of conditions a lag existing between technological developments and the application of such developments in medicine.

The lag so noted constitutes the major discrepancy in what should be and what actually is taught to medical students.

The technological developments concerned in this situation are in most cases those concerned with quantitative physical science. For example, in the first two years of the 1950's, research revealed the complete basic nature of the nerve impulse and its propogation. Unfortunately, this information is not being taught to the medical students because the entire explanation is based on a moderately complex mathematical analysis and our medical students are not capable of handling the mathematics involved.

In order to remedy this we must (a) teach the necessary mathematics in medical school, or (b) see that the students get the mathematics in premedical college. An examination of the problems concerned reveals that the medical student should have college algebra, trigonometry, and differential and integral calculus.

Now this plea for more mathematics is not the ravings of an heretic; it is simply a reaction to listening to countless groans which arise whenever one puts an equation on the blackboard. Such manifestations of failure to understand are discouraging to say the least.

Another and closely related need in the training of premedical students is more physics, and perhaps a different way of presenting physics. Part of this need arises from the recent rather tremendous surge in medical applications of physics and the development of biophysics as a separate discipline. Much of the need arises, however, because the physics presented in premedical college simply is not adequate.

The inadequacy of the present arrangement is at least in part because the premedical student does not get enough mathematics for thorough understanding of the principles of physics. In part, it also results because the teachers of physics make no attempt to show the student any reason for studying physics. "Physics for physics' sake" is the watchword in premedical courses.

Lastly, the timing of the physics courses is poor. Physics is generally given in the sophomore year of college, and it is three or more years before physics is referred to again. The forgetting curve takes its toll in this interim.

One can see another reason why physics has not been properly utilized in medicine if he examines the premedical curriculum comparatively. In chemistry, for example, the students get courses in inorganic chemistry, organic chemistry, qualitative and quantitative analysis, and in medical school, biochemistry. In all, a total of three years of courses are spent in getting adequate chemistry. In physics, on the contrary, the student gets only one year of somewhat diluted physics. Now physics is no less complicated than chemistry and so needs no less time for

its mastery; nor is it any less important than chemistry in understanding the phenomena of living matter. The conclusions are obvious: we are delinquent in teaching a major segment of premedical knowledge.

A third real need in the premedical curriculum is physical chemistry. Nowadays, we see studies of cancer, cirrhosis, blood dyscrasias, and many other clinical entities based on biophysical chemistry. Drug action, immunity, pathological processes, cell division, etc., all have physical chemical phenomena as their basis. How can the physician understand and use or treat these phenomena if he does not understand their background? He cannot!

These, then, are the needs. The medical student already carries twenty to twenty five hours of work, so that we cannot add these subjects to his medical curriculum without dropping out something else. Shall we drop out heart disease, or psychiatry, or polio, or obstetrics? Such a move would bring down the wrath of the whole medical profession on us, and would not endear us to the general public at all.

Suppose we examine the possibility of inserting these needed courses into the premedical curriculum. Again, examination shows that the premedical curriculum is full, and the arts and sciences people decry the lack of time for insertion of electives. But what are the subjects which so firmly pack the premedical schedule? One sees history, languages, social studies, philosophy, art, physical education, etc., which seem to have no immediate bearing on preparation for medicine. Can we eliminate some of these? Most medical school instructors agree that medical students are deficient in the use of the English language, and if we should recommend anything, we would recommend the addition of further training in grammar, sentence structure, and the art of expository writing.

Again, can we eliminate some of the less obviously valuable courses? "No," cries the arts administrator, "we must not drop anything that adds to the cultural development of this student." In fact, these administrators have gone so far as to say that they will not include any materials which may be construed as "preprofessional".

Now this attitude is not hard to understand, and one can even justify it if he looks from the proper direction. But which is more important or desirable, to have doctors who are technically deficient but highly cultured, or doctors who know their medicine but not their aesthetics?

This concept of the predominance of cultural subjects in college training is an extension of trends in grade and high school curricula. You all know that recently, educators have become aware that their past efforts have resulted in a sparcity of technical personnel, and now the pendulum is swinging back toward inclusion of technical subjects in the lower level schools. This must be done lest we strangle in our own intellectual blood for lack of nutrient technical training.

The physician's heritage is the knowledge of medicine. If acquisition of that knowledge requires changes in the premedical training, then we must make those changes. We must not deliberately be guilty of limitation of the ability of the physician trainee to understand his business. Such limitation would only be to our own detriment.

THE CLINICIAN'S VIEW ON THE PREPARATION OF PREMEDICAL STUDENTS

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When first asked to be a member of this panel, I was reluctant to assume the role of representing the clinician. One does not often think of the anesthesiologist as a representative of the field of clinical medicine. On second thought, however,

it does not seem entirely unreasonable. Anesthesiology is concerned with patients having all types of surgical procedures and who, in addition, may have all varieties of medical complications. We deal with sick patients who are emotionally disturbed, undergo surgical trauma, and receive toxic drugs.

Before deciding how to prepare a student for clinical medicine, let us consider what the physician does, for what the student is being prepared. In dealing with patients, the clinician must have patience and listen; he must evaluate the patients' complaints, which often are numerous and may have little bearing on the basic disease problem. The physical examination, laboratory reports, and x-ray may give valuable, or misleading, information. Having a mixture of facts, assumptions, and hunches, adding to this his general knowledge of human behavior, the physician must arrive at a tentative diagnosis and a course of action. The decision, of course, must be based on the knowledge of anatomy, physiology, pathology, and pharmacology. The diagnosis may be modified or changed as the course of the disease indicates, and the method of dealing with it may be modified or altered. At times manual dexterity may be required in order to carry out the course of action.

In what way can the pre-medical education contribute to the development of the physician? Certain traits are desirable, and certain knowledge is imperative if the physician is to be a capable practitioner. The medical school will provide the specific knowledge which the physician needs. The college should provide some basic knowledge, and foster the desirable characteristics. I will indicate some of them, attempt to point out why they are important, and perhaps what can be done by the college to develop them further.

1. Interest in people. The physician deals not with a disease, not with a germ, not with a pathological entity, but with a person who is troubled or sick. Many patients who seek the advice of a physician have no organic disturbance whatever. They may develop physical complaints based on emotional or psychologic disturbances; they are not psychotic. A large proportion of the work of the physician consists of listening to people and attempting to help them solve the problems of their life situation.

Even when organic disease is present, the psychological overlay, or the adjustment of the person to his disease, is a very important factor in the way he responds both to his disease and to his treatment. A patient may be cured of his physical illness, and go through life with a psychological or emotional disability.

For many patients, perhaps for most patients, the interest of the physician and his sympathy with their problems are of equal importance with the physical method of treatment. For this reason I believe that the pre-medical student should not only be interested in people but should learn more about them in his pre-medical courses by instruction in sociology, philosophy, psychology, history, and civics.

2. Sense of responsibility. Self-discipline and the sense of responsibility are primary attributes of a good physician. The physician is duty bound to keep his information up to date. When he encounters a problem with which he is not familiar, he must take the time, and make the effort, to learn what there is known of the subject before making a decision or giving advice to his patients. When the physician undertakes to provide medical care to a patient, he sometimes is faced with difficulties and time requirements far beyond what he had expected. The study, thought, and time required to care for the sick patient properly must be conscientiously provided.

The pre-medical student should be indoctrinated with the self-discipline and the feeling of responsibility to accomplish what is expected of him. In this regard I believe our pre-medical training is considerably lacking. In any college course a certain acquisition of knowledge is expected. We should not call the roll or in other ways compel the students to attend lectures. If the teacher is good, the

students will attend the lecture because of what they get out of it. If the teacher is not good, he should seek to improve himself rather than compel attendance by roll call. Having a sense of responsibility, the student will acquire the knowledge necessary to complete the course, whether it comes from lectures or individual study or both.

In keeping with this, I believe it might be well to give each student a project of considerable duration, with little supervision except that which the student requests. The completion of a project each semester would give the student practice in assuming responsibility, sustaining interest, and carrying through the necessary work.

3. *Method of thinking*. The method of thinking required for the successful practice of clinical medicine is somewhat different from that of the mathematician, the physicist, and the chemist. Medicine is not an exact science. On the contrary, sometimes, the so-called scientific part of medicine does not agree with the clinician's judgment; it is often wise to disregard the laboratory findings and to proceed on the basis of his opinions.

The type of reasoning which the physician must do is similar to that of the detective. Of all the minor abnormalities which every individual has, the physician must select and investigate the one or two which appear to be pertinent to the problem at hand. Of many dozens of possible laboratory studies, the physician must select a few which promise to have a bearing on the problem. He must pay attention to major factors in the overall picture, and yet must not ignore an apparently minor detail which may provide the clue for the solution of the problem.

How the pre-medical teacher can assist the student in acquiring this type of thinking process, I am not certain. Perhaps a course in logic might be of considerable value here. Perhaps problems in pre-medical classes might be deliberately complicated by the addition of much irrelevant material which the student will learn to recognize and eliminate. Thinking quickly is also important; the student should be stimulated to aim at rapid answers; place a premium on speed.

4. *Emphasis on function*. Function, not structure, is the concern of the physician. A knowledge of structure is important only in that it helps to understand function. I believe that the pre-medical courses place too much emphasis upon structural biological studies. In many respects these studies merely anticipate the subjects of the medical school. If any biological science at all is taught to the pre-medical student, it should probably be physiology, so the student becomes oriented to thinking in terms of function. Perhaps an integrated program of the biological sciences might be in order, using physiology as the focal point, with the other biological sciences included insofar as they contribute to an understanding of how the body works.

5. *Ability to communicate*. The ability to communicate with people is important for every physician. In this regard the pre-medical teaching program can do a great deal to improve the student who is sent on to the medical school. He should have a better working knowledge of the English language, both in speaking and writing; he should also have some training in public speaking.

As one of the intelligent and educated members of a community, the physician has the duty to take part in the activities of his town or city. He should also take part in his professional group's activities. Improvement of medical care is based not only on each physician's improving himself, but also on each helping to advance the knowledge or the skills of others. In both instances the ability to write well and to speak clearly is essential.

I have not commented on the need for the physician to be a scientist, to acquire a great deal of knowledge in the fields of mathematics, chemistry, physics. Extensive knowledge of these subjects is highly desirable. The pre-medical student, however, has only a certain amount of time in which to prepare himself for medical school. If his college course were eight years in length, many more subjects

could be added. Since only a four year period, sometimes less, is available for pre-medical training, the subjects should be selected and the time apportioned in such a way as to prepare the future physician for the assumption of his clinical responsibilities. The proportion of class hours devoted to the basic sciences might have to be curtailed. Would this seriously interfere with medical progress?

Some of the basic science courses merely anticipate what is taught in medical school, to make it easier for the student later. This should not be necessary. For the physician interested in the pursuit of a research project, deficiencies in knowledge in the basic sciences can be made up fairly rapidly by intense, motivated study, and by consultation with experts in the field. Of the information which he memorized in his basic science courses, only a smattering remains with the student when he enters the field of medical research five, six or more years after graduation from college.

To summarize, I believe the function of the pre-medical college is to foster the sense of responsibility and inculcate self-discipline in the student. The college should stimulate interest in people, and how they function in society. The student should learn to think of people as integrated functioning units of psychological, emotional, chemical and physical make-up. With the student prepared in this way, the medical school is better able to train good doctors.

PROBLEMS OF THE PREMEDICAL COLLEGE ADVISOR

R. A. HEFNER Ph. D.
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The hardy perennial problem of the premedical student, like the poor, the grasshopper, the plantain and the starling, is ever with us. Contrary to persistent belief in many quarters, our task is not of general elimination or extermination but a careful selection of fruitful seeds from the tares and the chaff by a laborious winnowing process. This selection is as ancient as the art of medicine. There is no record to indicate that the apprentices of Hippocrates or the students of Galen and Silvius had to demonstrate their proficiency in organic chemistry or be able to apply the laws of probability to a problem in heredity, but they doubtless faced other barriers to the promised land that were just as formidable.

There are no vague mysteries nor any secret abracadabras to the ritual that leads to acceptance into the medical school. Beyond a real desire for the study and practice of medicine the student needs only to demonstrate scholastic ability and achievement beyond the average academic level. How far beyond that level is a question that can best be answered in terms adjusted to the standards of his particular institution. The record in the sciences will come under particular scrutiny but the over-all scholastic standing is the basic consideration. There may be medical applicants who demonstrate achievements in English or Foreign Languages far beyond their ratings in science but such do not seem to attend our University.

If indoctrination and orientation, instead of selection, becomes a general policy for the initial year in Medical School, the task of premedical selection assumes a role which is even more significant in the future than it has been in the past. The net result of this selection must be a product which we can guarantee, physically, intellectually and morally. It would seem that the only guarantee that we may overlook is that of the ability of the student to finance a medical and post-doctoral program. That we have an effective system of selection in operation at Miami University is evidenced by the fact that but two out of 98 students admitted in the past seven years have failed to remain in the medical course.

At the beginning of his Sophomore year, our premedical student is assigned to an adviser (at present, these advisers are instructors in either Chemistry or Zoology). During the second semester of the Junior year, the student presents to his adviser the names of five instructors who will submit recommendations in his behalf. The adviser sends a formal recommendation blank to each of these five instructors with a request for completion and return by a given date. This blank is reproduced at the end of these remarks.

These five recommendations (we will act on a minimum of four) are summarized by the adviser and presented to a premedical committee which makes an over-all evaluation upon which the final recommendation is based. Our designations in this summary evaluation follow:

without reservation	________	fair	________
strong	________	doubtful	________
well	________	not recommended	________

This evaluation is put in the form of a letter which goes out to the Medical Schools and presents a comparative evaluation of scholastic achievement, personality, character, ACE scores and extra-curricular activities. We feel that the final rating on all these bases is not only a mark of present accomplishment but a fair estimate of probable success in medical school. An example of the letter form follows:

MIAMI UNIVERSITY

OXFORD, OHIO

COLLEGE OF ARTS AND SCIENCE
122 Upham Hall
WILLIAM E. ALDERMAN, *Dean*
JAMES H. ST. JOHN, *Assistant Dean*

Gentlemen:

The following information concerning________________________________is furnished you by our Committee on Qualifications of Students for Medicine. This recommendation is based on information supplied to us by various instructors, using a form similiar to this letter.

We have the following test scores for this student. Test scores are percentile ratings on national norms.

A.C.E. Intelligence: Quantitative______Linguistic______Total______

Activities indicating leadership and social interests are listed below:

On the basis of the above information, from reports of instructors, from his scholastic achievement, and from personal acquaintance with the candidate, the Committee as a whole makes the following recommendation:

The committee considers that this recommendation should be regarded as:

without reservation	________	fair	________
strong	________	doubtful	________
well	________	not recommended	________

It is recommended that this recommendation take the place of letters from individual instructors. If these are desired in addition, please notify us.

Sincerely yours,

____
For the Committee

The foregoing committee recommendation was based on the following information supplied by these instructors:

How well does he work? (especially in laboratory)

efficiently		adequately		inefficiently
speedily		average		ploddingly
thoroughly		adequately		superficially
complete independence	minimum help	average	quite dependent	completely dependent
neatly		average		sloppily

Scholastic interest:

With respect to originality:

highly original	somewhat original	lacks originality	no originality

With respect to initiative:

strong initiative	needs starting push	considerable leading needed	complete follower

How well does he reason?

clearly and concisely	arrives deviously but can usually be led	hazy	often does not follow	cannot reason

Reading within science area:

broad background	keeps up	minimum amount

Reading in other areas:

broad	average	narrow

Personality and appearance:

He gets along with his fellows:

minimum friction	average	much friction

He is:

quiet	average	lively
reserved	average	forthright
fully cooperative	average	uncooperative

His emotional balance:

apathetic, unresponsive	often fails to respond	well-balanced	occasional emotional outbursts	over-emotional

Professionally, his appearance would:

favor him	be average	hinder him

He is:

over meticulous	neat	average	untidy	sloppy

Comment on qualities of leadership:
Culture, background, good taste, good manners:
He is thoroughly trustworthy:
Instances of dishonesty:
In what respect does he impress you most favorably?
In what respect does he impress you least favorably?
Estimate of success in medical school:
How good a physician will he be?
How should he be recommended by Miami?

without reservation	strong	well	fair	doubtful	not recommended

SUMMARY OF COMMENTS MADE IN OPEN DISCUSSION

(Editor's note: After the formal presentation of the foregoing papers, the meeting was thrown open to discussion from the floor. This discussion was lively, and was carried on by a number of people from the audience in addition to the formal participants. The comments were tape recorded, but were so lengthy as to preclude publishing in their entirety. Therefore, we have attempted to abstract the major ideas from the recording. There is no attempt to identify the commentors or to present these ideas in the same chronological order in which they appeared. Please accept our apology for misquotes or deletions, all of which are entirely unintentional.)—RWS.

Early in the period of open discussion, one of the major problems of premedical education was laid bare. This is that there is often a discrepancy between what the medical college catalog lists as required of the student and what the student actually needs when he gets into medical college. It would appear that this problem is widespread, and has occupied a major portion of the attention of several large meetings (*e.g.*, recent meetings on premedical education in Chicago).

In later remarks, it was pointed out that the nature and extent of catalog material per se has been the subject of national meetings of medical educators and that the concensus of opinion is that the catalog material should represent only a guidepost of minima for premedical preparation. Thus, the premedical adviser and his prospective medical student should use the medical college catalog only as a skeleton structure, and should build his general preparation around this structure.

A later comment from the floor pointed out that in many cases, the medical college admissions boards take the requirements they put into the catalogs as absolute. For example, a situation was described where two students had received all the preparation they needed, but because of difficulties in scheduling could not obtain the last semester of the laboratory of organic chemistry. These students were accepted for medical school only on condition that they acquire this last bit of academic work. The commentor felt that the extra time and effort and expense involved on the part of the students was out of proportion to the benefit they would derive from finishing the course. He then pointed out that there existed a disagreement between what the medical college administrators say is their policy and what they actually put into practice.

One of the major points of discussion arising in this meeting was concerned with the difference in outlook of the clinician and the preclinical scientist. It was stated that one cannot hope to understand and treat the human body without first obtaining a knowledge of the structure and function of the body. It is likely that the lag which exists between discovery of fundamental phenomena and their application in medicine is largely due to failure to understand the principles underlying the discovery.

The basic scientist (*i.e.*, the preclinical professor) was referred to in partial jest as a "sadist" who wanted to make it as tough as possible on the student. Certainly this term would apply to only a few such individuals. An anatomist in the audience emphasized his frequent disappointment at the student's lack of basic preparation, but pointed out that perhaps this was because the basic science professor thinks of the kind of student he would *like* to teach rather than the physician which he is charged to train.

It was then stated that the physics and mathematics which were recommended additions (see formal presentations) were actually quite elementary in scope, and the proponents did not want to make mathematicians or physicists out of the students at all. An example was given of an instance where graduate physicians were using an important technique for therapy on the basis of physical principles which did not apply to the system with which they were working. It was suggested that the physician we are now training may be deficient in important information without knowing it.

The clinician, on the other hand, is more interested in how the student purports

himself in the clinic and hospital than in how much detailed scientific information he has acquired. Indeed, in this respect the clinician sometimes disagrees with the medical college administration. It was pointed out that the trainee under discussion is *not* the ultimate medical researcher, for such men are unique and can obtain the special training needed independently. Some of those present disagreed with this general concept, and expressed the feeling that research was important to the practicing physician as well as the clinic or hospital physician.

It was reemphasized that if there were not disagreement about these problems, there would be no reason for having such a meeting as this. One commentor who is himself a clinician stated that students do indeed need to know the basic science of their profession, but perhaps even more important is that he must learn to assume responsibility and he must like and take an interest in his patient. This question of instilling into the medical student the attributes of responsibility and love of the human race was discussed at considerable length. It would appear that the real question is whether it is possible to teach these esoteric qualities as such, and whether such qualities would not be useless without sufficient technical training.

At various times during the discussion, the question of evaluation of student performance was raised. From the premedical advisers' point of view, evaluation was in terms of the percentage of their students who were accepted to medical school, and occasionally in terms of the number of such students who completed medical school successfully.

The medical college administrator, on the other hand, evaluates his students on the basis of success in getting the students placed in internships and residencies of their choice. Also, it was pointed out that the major criterion of success in training physicians is the fate of the physician after he has been out of medical school for several years. It was felt that if the community (here it was emphasized that this applies especially in small communities in the absence of large well equipped and staffed clinics) trusts and depends on the physician, then that physician must have been well trained. This implies, of course, that the general public is intelligently critical, which the commentor believes is so.

A problem which occasionally arises from relations between the premedical advisers and the medical college was cited. As an example, the commentor described a case in which a student was highly recommended by his premedical college but was found at interview to have a police record. The admissions committee in this case was hard put to arrive at a decision on this student because his premedical advisers insisted he was completely rehabilitated. Still, the acceptance of a student with any question of social irresponsibility is a grave and serious matter. The point of these comments was the restatement of the tremendous responsibility of the admissions committee and the fact that the committee often is faced with problems which are very difficult of solution.

One commentor neatly stated his position with respect to the general aims of the premedical college. He felt that students who had majored in sociology or history or languages could acquire the scientific background they needed in a few courses and would make just as good physicians as those who had spent the majority of their time in technical background training. Obviously, there were persons present who disagreed with this point of view, and others who agreed with it.

This, then, is the gist of the ideas presented in open discussion. At the end of the meeting, one fact had become increasingly apparent: there is a need for more such meetings.

THE HOST RELATIONSHIP OF A MILTOGRAMMID FLY SENOTAINIA TRILINEATA (VDW).

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The fossorial hymenoptera and their predator-parasite complex have fascinated entomologists since the days of Fabre. The paucity of data, however, in America, about the habits of the sarcophagid flies of the tribe miltogrammini, leaves many gaps in the understanding of their behavior patterns.

Fabre (1917) published a detailed and interesting acount of the habits of a miltogrammid, although inaccuracies are apparent. Smith (1923) watched *S. trilineata* and another species of Senotainia dart into the hole after a species of *Bicyrtes* as it brought in its prey. Evans (1953) published a note on the host of *S. trilineata* and of *S. littoralis* Allen. Krombein (1953) included a few notes on the habits of *littoralis*. Allen (1926) compiled the most complete observations in America, of the habits of *S. trilineata*, *S. vigilans* Allen, *Phrosinella fulvicornis* (Coq.) and *Metopia leucocephala* (Rossi). Other authors have published papers on the habits of other species in this tribe. Newcomer (1930) wrote a short but accurate report on *Hilarella hilarella* (Zett.) and LaRivers (1944) described the habits of *Eumacronychia elita* Town. and its relationship to the Mormon cricket.

Although *trilineata* is the best known species in this tribe, its elusive habits have discouraged many entomologists. Detailed life history studies have not been published and information is scarce, incomplete and inaccurate on the host relationship of these flies.

In the New World, Allen (1926) has published the best paper on the habits of *trilineata*, also. He surmised that this pesky fly is stimulated to larviposit only in the presence of a wasp bringing in prey. Allen has said,[2] "The habit of shadowing the host as it carries its prey to its nest seems to be more highly developed in this genus than in any other group. Except for *Pachyopthalmus*, *Senotainia* is the only genus in which the facets in the front part of the eye, of the female, are very large as compared with the facets of the male." Fabre said of some miltogrammid, "It is an absolute rule that the Gnat never enters the burrow."

Allen says that J. B. Parker captured *S. vigilans* emerging from a hole dug by *Bembix spinolae* Lep. Allen, however, implies that *vigilans* is also stimulated to larviposit in a situation where the wasp is transporting its prey. Although *vigilans* is not as abundant as *trilineata*, in Maine, I have yet to see *vigilans* crawling into the burrows unless it was pursuing a wasp.

In my studies of the predator-parasite complex of *Chlorion ichneumoneum* (L.) in Ithaca, I frequently observed *Metopia campestris* Fall. and *M. leucocephala* crawl into the burrows but never *trilineata*. Many observations were made, however, of *trilineata* chasing a wasp carrying a long-horned grasshopper. In these situations the wasp was always carrying its prey. Frequently one wasp was pursued by as many as four flies. These persistent flies chased the great-golden digger wasp back and forth—as many as fifteen times. When a fatigued wasp dropped to the ground, the flies stopped their stalking. When the wasp moved the flies resumed their hovering positions. Commonly the harassing miltogrammids darted near the hole after the wasp but retreated immediately, after the wasp deposited the tettigoniid at the entrance. Likewise the flies withdrew if a distraught wasp abandoned the long-horned grasshopper.

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[2]Page 20.

At that time I did not have the vision to examine the prey for maggots which undoubtedly the flies deposited on the grasshopper being transported by the wasp. In the summer of 1953, while study the digging hymenoptera in the so-called "Deserts of Maine", (Freeport and Leeds), figure 1, I began examining the prey caught by *Philanthus solivagus* Say, *Aphilanthops frigidus* (Sm.) and *Microbembex monodonta* (Say). The kind of prey are listed in table 1 but only the winged ants which *Microbembex* carried were inspected.

Most of the winged ants carried by *Aphilanthops* had one or more maggots on some parts of its anatomy. Some ants had as many as nine maggots distributed over their appendages either singly or in groups. Many of the bees captured by *Philanthus*, however, were either free of maggots or had only several.

FIGURE 1. Desert of Maine, Freeport, Maine. (Courtesy of Mike Roberts Color Production)

TABLE 1

List of prey captured by digging hymenoptera at the "Deserts of Maine". (Freeport and Leeds)—1953

Aphilanthops frigidus	Philanthus solivagus	*Microbembex monodonta*
Formica fusca var. *subsericea* Say (all winged)	*Halictus ligatus* Say	*Halictus pectoralis* (alive)
	H. pectoralis Sm.	*Formica fusca* (alive)
	H. rubicundus (Christ.)	Other ants (dead and alive)
	Ectemnius sp.	Chrysomelid larva (dead)
	Andrena sp.	*Heliria* (Membracid) (dead)
	Eumenes sp.	*Brachyrhinus ovatus* (L.) (dead)
		Psylla sp. (alive)
		Vespula parts of
		*Coccinella transversaquatta*a Fald. (dead and alive)
		Histerid, part of a

That the maggots were more common on the ants than on the bees can be attributed to the habits of the wasps. *Aphilanthops* carries its prey loosely, thus it provides a visible target for the swift, harassing flies, whereas *Philanthus* carries the bees tightly against its venter.

Bees and ants were intercepted from the homing wasps and examined. About fifty maggots were collected on the hosts. These "parasitized" prey were placed in shallow jelly glasses and covered with moist sand from the area. A perforated lid was placed on each glass. The glasses were stored at 80° F. ± 2, one week later. Water was added at least once weekly to keep the soil moist.

Table 2 shows that the larval period lasted 7 to 10 days. Approximately ⅓ of the puparia were small. The food supply may have controlled the size of the larvae and the length of the larval period. One glass container with seventeen maggots contained most of the small puparia.

The amazing situation, however, was the erratic and prolonged pupation period. Most of the maggots pupated within several days of each other, yet the adults emerged over a four month period. Three of the flies may have emerged six months after the maggots pupated. Schmeider (1933) showed that in *Melittobia*, a gregarious Eulophid parasite, the larval nutrition determined the incidence

TABLE 2

Biological notes on the Miltogrammid fly Senotainia trilineata and its host relationship—Freeport and Leeds, Maine—1953

Date Larvae Collected, Number, Larval Period	Date of Adult Emergence at 80 F	Sex	Time Emerged	Wasp Which Collected prey	Prey Upon Which Larvae Found	Location and Number of Larvae on Host
8-15-53 (17)*	(1) 11-23-53	male	early morn	*Aphilanthops*	(2) *Formica fusca*	(a) (2) tip of abdomen,
	(1) 11-30-53	female	" "	*frigida* (sm.)	var. *subsericea*	(3) left side
7 to 9 days counting	(1) 1-29-54	male	4 PM		(winged only)	of abdomen, (4)
the prepupal period	(1) 2-21-54	female	night			neck ventral
	(1) 2-23-54 **	male	5 PM			(b) (4) on mentum, (1) mandibles
	(1) 3-17-54	female	night			(c) (2) abdomen dorsal
	(1) 3-24-54	male	———			(d) (1) middle femur
	(1) 3-31-54***	female	8 AM			(e) (2) right side of abdomen
	(1) 6-14-54	male (70% Emergence)	———			(f) Two without larvae
8-12-53 (13)*	(1) 11-10-53	male	———	*Aphilanthops*	(1) *Formica fusca*	
	(1) 11-14-53	female	morn	*frigida* (Sm.)	var. *subsericea*	
9 to 11 days counting	(1) 11-30-53	male	night		(winged only)	
the prepupal period	(1) 1-21-54	female	night			
	(1) 1-27-54	male	"			
	(1) 2-16-54	male	"			
	(1) 3- 5-54**	female	"			
	(1) 3-16-54	male	5 PM			
	(1) 3-31-54***	male	night			
	(2) 6-14-54	female, male (100% Emergence)	———			
8-14-53 (4)	(1) 12- 1-53	female	8 PM	*Philanthus*	(2) *Halictus* Sp.	(a) (2) on middle femur
	(1) 1-25-54	male	night	*solivagus* Say	*Andrena* Sp.	
10 days, counting	(1) 1-28-54	female	4 PM			(b) (2) abdomen dorsal
the prepupal period	(1) 3-17-54	female (100% Emergence)	5 PM			(c) many without larvae
8-12-53 (5)	(1) 11-24-53	female	———	*Microbembex.*	(2) *F. fusca*	
	(1) 1- 9-54	male	morn	*monodonta*	var. *subsericea*	
	(1) 1-26-54	female	———			
	(1) 2- 6-54	male	5 PM			
	(1) 3- 6-54	male (100% Emergence)	———			

1. Freeport
2. Leeds

* Preserved Several
** Test temporarily abandoned, soil dry
*** Test abandoned 3-31-54, soil dry

of diapause. Simmonds (1948) demonstrated that the age of the adult and temperature, at least in *Spalargia drosophilae* Ash., a hymenopterous parasite, controlled the number of pupae that diapaused. These, of course, are examples from another order. The first flies emerged in November, about three months after the maggots were collected. The next series did not appear until January—

a lapse of 6 to 8 weeks' In three of the glasses, the third series did not appear for 3 to 6 weeks. The last series, under controlled conditions, emerged in March, 3 to 4 weeks later. After March 5, the sand was not moistened, nevertheless five flies survived and came through two and three weeks hence. On March 31, the experiment was discontinued but the contents of the glasses were not sifted. Three more adults were found on the sand on June 14.

Eight-three percent of the maggots metamorphosed into adults, and all of these flies were *S. trilineata*!

From this small, random sample we could surmise that only *trilineata*, in this area, larviposits on the prey while the prey is being carried by a fossorial hymenopteron. This sample of prey and maggots may not be representative, therefore a more exhaustive survey should be made in areas where *S. vigilans* is more abundant and *S. littoralis* is present.

Phrosinella fulvicornis[3] was the most common sarcophagid in these "sand deserts" but it is a "hole searcher" like *Opsidia gonioides* (Coq.), therefore the larviposition response could be initiated in situations other than a wasp bringing in its prey. *Metopia campestris* and *M. leucocephala* are "hole crawlers", so here again larviposition on the prey in flight would be an exception to the pattern.

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[3]I have several records of *P. fulvicornis* hovering over *Bembix spinolae* and harassing the wasp.

STUDY OF SOME CHEMICALLY ANALYZED OHIO CLAYS BY X-RAY DIFFRACTION AND DIFFERENTIAL THERMAL ANALYSIS

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Several studies of Ohio clays have been completed in past years principally by means of chemical and microscopic methods, and the results were related to ceramic properties and uses. Noteworthy among the earlier studies are those of Stout *et al.* (1923) on the coal formation clays; Lamborn *et al.* (1938) on shales and surface clays; Stout *et al.* (1931) on the Lawrence clay; and Stout (1940) on the Clarion clay. Recently the use of two methods of mineralogical analysis, namely x-ray diffraction and differential thermal analysis (d.t.a.), have become increasingly significant in their adaptability to the study of clays and shales. These techniques reportedly lend themselves to quantitative or semi-quantitative determinations of the minerals present in clays.

The earlier studies made no attempt to determine the relative amounts of the individual mineral species found in the clays although it was realized that the variations in the mineral content were responsible for the variations in the ceramic properties. As an initial project of several proposed investigations of Ohio clays, about 40 of the chemically analyzed and petrographically examined coal formation clays, originally described by Stout *et al.* (1923), were restudied by the more modern x-ray and d.t.a. methods. This study had the objectives of (1) determining quantitatively the minerals present, (2) attempting to correlate the chemical data with the several mineralogical phases present, and (3) evaluating the ceramic characteristics in terms of differences in mineral compositions.

All specimens studied are from clays which underlay the coals of Pennsylvanian age in eastern and southeastern Ohio. A detailed description of each clay, including its geological and geographical occurrence, as well as the results of petrographic study and ceramic tests, are given in Stout *et al.* (1923). Each sample studied and reported in this paper is numbered to correspond with the page in Stout *et al.* (1923) on which the chemical analysis appears. Other pertinent data, such as the petrographic examination and ceramic tests, are given in appropriate sections of the same work.

EQUIPMENT AND METHOD OF STUDY

Differential thermal analysis (d.t.a.) consists of detecting and recording thermal effects that occur at different temperatures. As applied here, it measures the changes in thermal energy content of a material while the temperature is raised 10° per min. from room temperature to about 1050°C. The equipment used in this study is essentially identical with that described by McConnell and Earley (1951). Thermograms were obtained for all samples except number 127.

Filtered copper x-radiation was used throughout the study. Powder diffraction photographs (using a camera diameter of 114.6 mm.) and x-ray goniometric measurements were obtained for all samples using the Norelco "large-angle" apparatus. For these measurements, bulk samples were used, rather than fractions (*e.g.*, finer than 2 microns), because: (1) there is reason to believe the samples had been ground prior to chemical analysis at the time of original study (Stout *et al.*, 1923), and thus the present size distribution is not representative of the original clay; (2) only small amounts of some specimens were available; (3) experimentation has shown that the same proportions of the clay minerals are indicated by bulk

samples as by sedimented fractions, although the intensity maxima for sedimented materials are usually larger; and (4) the chemical analyses were made on the same bulk clays rather than any particular fraction. The use in our x-ray studies of compacted samples, rather than sedimented samples, seems to be justified by the results of Mitchell (1953). He found that well oriented samples could be obtained by compaction.

Without additional qualitative mineralogical information, a chemical analysis of a clay is of limited value in deducing either the mineral composition of the clay or its usefullness to the ceramic industry. For example, the following samples, all from the same clay bed (Lower Kittanning) and from the same mine in Tuscarawas County, show the following percentages of some significant constituents (Stout *et al.*, 1923):

Number	SiO_2	Al_2O_3	K_2O	Position in bed
313	54.16	25.12	1.71	Top
314	52.31	29.52	.34	Middle
316	55.93	24.83	3.02	Lower part

If it is known that these clays contain kaolinite and mica, however, the ratios of these minerals might be surmised from the K_2O content to be approximately 1 : 1.2, 1 : 0.3 and 1 : 2.2, respectively, as found by a combination of methods. McCaughey (Stout *et al.*, 1923) employed the petrographic microscope, whereas the present investigations attempted to obtain correlations by other means.

The quantitative estimations by means of x-ray diffraction were made by using the method of Murray (1954a). Murray (p. 57) calculated the theoretical diffracting power of the (001) plane of kaolinite to be about three times that of the (001) plane of a mica (so-called "illite"). From measurement of the intensities from the basal planes of kaolinite and "illite," the relative proportions of these clay minerals were determined. The method is subject to criticism, however, because it is known that kaolinites and "illites" show variable intensities of reflection depending upon differences in perfection of crystallization, isomorphous substitution (particularly of Fe), and crystal size. Nevertheless, this method still seems to be reliable and, as will be shown below, other methods are less so. This procedure appears to give good semi-quantitative results.

Qualitative or semi-quantitative information was obtained also from the powder diffraction patterns and from the thermograms. Finally the chemical data were calculated in such a manner as to give the best correlations with the other determinations.

MINERALOGICAL COMPOSITION OF THE CLAYS

As pointed out by Stout *et al.* (1923) the clays of Ohio are rocks; that is, they are composed of several minerals in varying proportions and are rarely uniform for any large area. In particular, the Ohio underclays are composed chiefly of a micaceous constituent, kaolinite and quartz. Usually these three principal minerals comprise 90 to 95 percent of the clay. Other substances found in small amounts in practically all the underclays are rutile, limonite, pyrite, siderite and organic matter. Occasionally, calcite, dolomite, zircon, tourmaline, etc. were found. Our discussion of the minerals in the clays will be limited primarily to the micaceous mineral, kaolinite, and quartz, although other minerals that were detected by d.t.a. or x-ray analysis will be noted.

The Micaceous Minerals

In his petrographic descriptions of the individual samples, McCaughey (Stout *et al.*, 1923) refers to "muscovite" and "sericite," the distinction being that the

former occurs as bright, splendent flakes of relatively large size usually in the "sand" fraction, whereas the latter occurs as fine needles or shreds in the "clay" portion. The term "illite," which is commonly used today to describe the micaceous constituent of argillaceous sediments, was not proposed until 1937 by Grim, Bray and Bradley. "Illite" has subsequently been applied to micas with a considerable range in composition, some of which are high in silica and water and low in potash when compared with muscovite (Grim *et al.*, 1937). Other persons have used "illite" for micas of sedimentary rocks which have a normal silica content but are high in water and low in potash. The latter are often called hydromuscovite or hydrous mica. Carr *et al.* (1953) have described hydrous mica from a Yorkshire fireclay, which is considered to be remarkably well developed and has a normal silica content. It is possible that the material originally called "muscovite" (Stout *et al.*, 1923) may be similar in composition as well as size and crystalline development but, inasmuch as the pure mica has not been chemically analyzed, this supposition cannot be verified.

A small amount of coarse-grained mica of specimen 342 has been isolated from the fraction which did not pass a 50 mesh screen, and some flakes are as large as ¾ mm. Although a detailed description of the micaceous constituents in the Ohio underclays has not been undertaken, preliminary examination shows the mica to have the optic angle characteristic of muscovite (approx. 35°). X-ray study indicates that this mica is the 2-layer monoclinic (2M) muscovite-type polymorph. In order to compare the crystalline properties of the large mica flakes with the fine-grained material ("sericite") from the same sample, a fraction which passed the 325 mesh screen was heated at 600°C for half an hour so that the structure of any kaolinite present would be destroyed. Only the x-ray diffraction lines characteristic of a 2M polymorph (in addition to weak lines of quartz) were observed, indicating that the coarse and fine flakes are virtually identical structurally after such treatment. The fine-grained mica of specimen 206 was studied similarly with similar results. In both cases the x-ray lines were remarkably sharp considering the small particle size. An attempt was made to determine the structure of the micaceous constituent in the fine fractions (2 microns and finer) of several specimens, but the results were inconclusive. The various mica polymorphs of illite or hydrous mica, as well as their identification, are discussed by Levinson (1955) and Yoder and Eugster (1955).

Table 1 shows that the micaceous constituent is commonly the most abundant of the clay minerals and also the most abundant of all minerals. Further investigation of the micaceous minerals in the underclays may reveal that the coarse-grained flakes have chemical properties similar to those of the hydrous mica described by Carr *et al.* (1953), whereas the finest grained mica may have a chemical composition similar to the illites described by Grim (1937). It is also possible that polymorphic structures other than 2M will be found. In addition some mixed-layer clays may be present because a few specimens (402, 453, 468, etc.) show the normal 10Å mica reflection to be broad and slightly displaced toward a smaller diffraction angle. Treatment with ethylene glycol failed to indicate any expandable layers among those specimens with suspected mixed-layers structures, but the possibility of a chlorite or some other non-expandable mixed-layer clay mineral remains. The thermograms, with the possible exception of specimens 313, 314, 327 and 402, show no indication of any clay mineral other than kaolinite or illite, although admittedly some of the thermal reactions could be too small to be recorded. The same four specimens showed a small endotherm at approximately 750°C. Although this valley is characteristic of some chlorites, no chlorite could be positively identified by x-ray methods and thus the significance of this d.t.a. inflection remains to be explained. On the basis of the work of Yoder and Eugster (1955) montmorillonite or some mixed-layer structure was suspected, but none could be identified with certainty either by d.t.a. or x-ray methods.

Kaolinite

Throughout the work of Stout *et al.* (1923) "clay" has been used both to denote a fine particle size (the clay separate or fraction) and a rock composition—principally a mixture of a mica, kaolinite and quartz. Only in a few places does "kaolinite" appear in the mineralogical descriptions. However, it should be emphasized that it is kaolinite which gives some of the Ohio clays their plasticity and other desirable ceramic properties.

TABLE 1

Ratios of illite to kaolinite and types of thermograms for Ohio coal measure clays

*Sample Number**	*Source Formation*	*Illite to Kaolinite*	*Thermogram*
127	Sciotoville	0.3	Not obtained
140	Sciotoville	3.3	Type 2
152	Quakertown	4.5	Similar to type 2
164	Middle Mercer	4.0	Similar to type 2
170	Flint Ridge	1.4	Type 4
178	Flint Ridge	2.2	Similar to type 2
184	Upper Mercer	3.7	Similar to type 2
193	Bedford	2.4	Similar to type 2
199	Tionesta	0.8	Similar to type 1
206	Tionesta	1.5	Similar to type 4
210	Tionesta	2.0	Similar to type 4
230	Brookville	3.0	Similar to types 3 (pyrite) and 4
233	Brookville	0.9	Similar to types 3 (pyrite) and 4
236	Brookville	1.9	Similar to type 4
252	Clarion	1.8	Similar to type 4
258	Clarion	0.8	Similar to type 1
262	Clarion	1.7	Similar to type 4
264	Clarion	2.1	Similar to type 2
279	Lower Kittanning	1.1	Similar to type 4
291	Lower Kittanning	1.6	Similar to type 4
301	Lower Kittanning	0.8	Similar to type 4
307	Lower Kittanning	1.0	Similar to type 4
{313**	Lower Kittanning	1.2	Similar to types 3 (pyrite) and 4
{314	Lower Kittanning	0.3	Similar to types 1 and 3 (pyrite)
{316	Lower Kittanning	2.2	Similar to types 2 and 3 (pyrite)
324	Lower Kittanning	1.1	Similar to type 4
327	Lower Kittanning	0.0	Similar to types 1 and 3 (pyrite)
{341	Lower Kittanning	1.7	Similar to types 3 (pyrite) and 4
{342	Lower Kittanning	2.9	Similar to types 2 and 3 (pyrite)
346	Lower Kittanning	2.5	Similar to types 2 and 3 (pyrite)
348	Lower Kittanning	2.9	Similar to types 2 and 3 (pyrite)
350	Lower Kittanning	2.7	Similar to types 2 and 3 (pyrite)
375	Oak Hill	2.4	Similar to type 2
379	Oak Hill	0.0	Type 1
402	Middle Kittanning	1.5	Similar to types 3 (pyrite) and 4
404	Middle Kittanning	2.8	Similar to types 2 and 3 (pyrite)
412	Middle Kittanning	3.2	Similar to type 2
{437	Upper Freeport	1.8	Similar to type 2
{438	Upper Freeport	2.5	Similar to type 2
446	Mahoning	1.4	Similar to type 4
453	Anderson	3.0	Similar to types 2 and 3 (calcite)
468	Meigs Creek	4.0	Similar to type 3 and 3 (pyrite and coal)

* The number of each sample corresponds with the page in Stout *et al.* (1923) on which the chemical analysis of the sample is given. Detailed mineralogical descriptions and results of ceramic tests may be found on the same and adjoining pages of the same reference.

** Specimens such as 313, 314 and 316, which are bracketed, are from different elevations of the same clay formation at one particular location.

Brindley and Robinson (1947) have shown that the kaolinite-type mineral found in fireclays (synonymous with underclay or "coal measures" clay) is structurally distinctive from other kaolinite-type minerals. In particular, it appears to be a member of the series intermediate between very well crystallized kaolinite which gives sharp diffraction lines and very poorly crystallized metahalloysite which generally gives broad, diffuse bands. Murray (1954b) has studied a similar series and shown that there are characteristic differences in the size of d.t.a. inflections among kaolinites, depending upon the perfection of crystallization.

Using the criteria established by Brindley and Robinson (1947) and Murray (1954b), we have found that the kaolinite in the coal formations is of two general types. The flint clays (314, 327, 379) and specimen 127 have structures which may be classed as well crystallized kaolinites; noteworthy is the fact that these are the clays with smallest concentrations of mica and quartz. The high degree of crystallinity is implied by the intense reflections at approximately 4.35 and 4.17 Å. Furthermore, reflections at 4.17 and 4.12 Å were resolved for the three flint clays, thus satisfying Brindley's (1951 p. 51) criterion for a well crystallized kaolinite. All other kaolinites of the underclays give x-ray patterns which are characterized by a poorer degree of crystallinity, either similar to Brindley and Robinson's (1947) "fireclay" with a weak reflection at about 4.14 Å, or similar to the better of the several poorly crystallized kaolinites described by Murray (1954b) as not giving this reflection. Nevertheless, these kaolinites do not approach closely either metahalloysite or dehydrated halloysite of the authors cited. In general, it may be said that the vast majority of kaolinites in the underclays show similarities in crystallographic perfection; the four notable exceptions have been cited above.

Quartz

The third abundant mineral in the underclays is quartz. It is found in two types of occurrence: (1) in relatively coarse and probably detrital grains in the "sand" fraction or (2) as very small grains intimately associated with the kaolinite and illite of the clay fraction and in clay aggregates. Stout *et al.* (1923, p. 519) suggest the possible occurrence of some secondary quartz in the form of chalcedony. The quantity of quartz varies considerably. In a few cases it may be virtually absent, as in specimen 127, whereas in others (*e.g.*, specimen 342) it may compromise at least 40 percent of the clay.

DIFFERENTIAL THERMAL ANALYSIS

Figure 1 illustrates several characteristics of the thermograms obtained from the Ohio clays, as well as those for several pure minerals. As a generalization the following types are represented:

(1) *High-kaolinite clays* exhibit a large endothermal valley at about 600°C and a large exothermal peak at about 950°C. The 950°C peak is uniquely attributable to kaolinite, and its intensity has been used by some persons as an indication of the degree of crystallinity. The 600°C valley, on the other hand, may result in part from the thermal effects of illite and quartz. The high-kaolinite clays are usually low in illite and quartz and are illustrated ideally by the flint clays.

(2) *High-illite*, low-kaolinite clays exhibit subdued endothermal valleys at 600°C because the thermal reaction of illite is proportionately much smaller than that of kaolinite. They give a subdued, broad, exothermal 950°C peak because of the low kaolinite content. A second endothermal valley for illite (at about 900°C) precedes the 950°C exothermal peak of kaolinite and is often discernable. The relative intensities of the 900°C and 950°C inflections may be used as a rough indication of the clay mineral content. A clay high in quartz, low in illite and containing some kaolinite would give a similar curve.

(3) *Clays with specific impurities* are easily recognized. Pyrite, for example, can be detected in concentrations as small as two percent by means of its peak in the range 400–500°C. Calcite was found in sample 453 by means of its valley at about 850°C; its presence was confirmed by x-ray methods. Coal fragments were found in sample 468 by means of a large exothermal peak in the vicinity of 700°C.

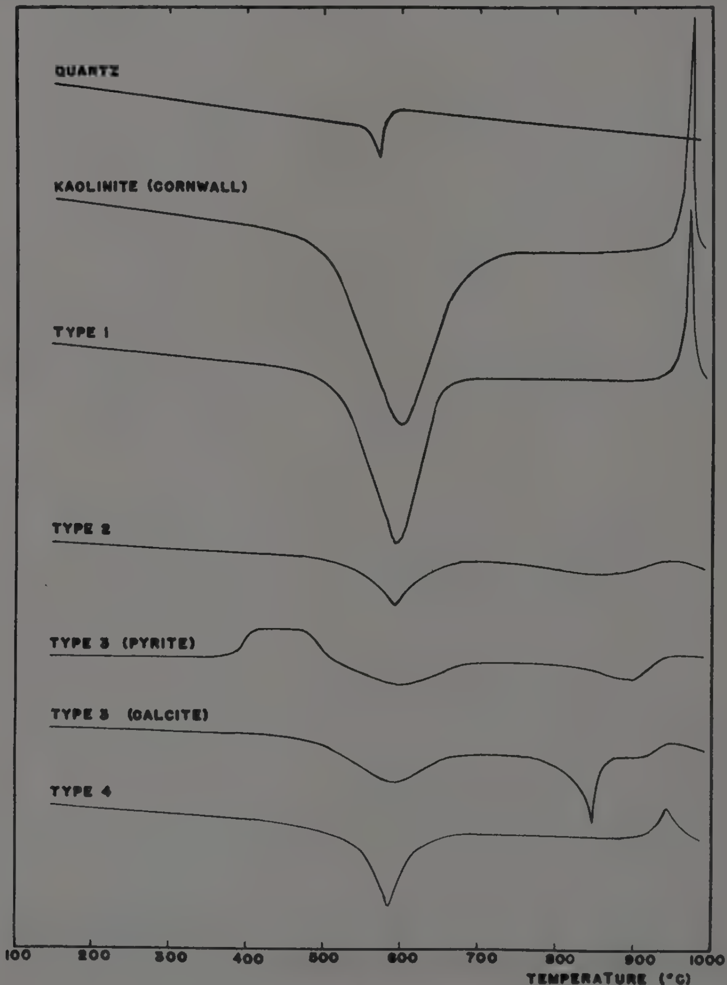

FIGURE 1. Thermograms of: 1. Quartz (Novaculite), Arkansas. 2. Kaolinite, Cornwall, England. 3. Type 1, specimen No. 379. 4. Type 2, specimen No. 140. 5. Type 3 (pyrite), specimen No. 468. 6. Type 3 (calcite), specimen No. 453. 7. Type 4, specimen No. 170.

Inasmuch as practically all the clays contained enough organic matter to mask or decrease the intensity of thermal effects near 500°C, all samples were treated with 30 percent hydrogen peroxide in order to eliminate the organic matter. The presence of significant amounts of quartz usually cannot be detected by d.t.a. methods in the presence of even small quantities of kaolinite and illite because the 573°C valley corresponding to the quartz inversion is relatively small. In table 1, clays containing significant amounts of the impurities noted are classified as type 3 and are further classified according to other characteristics.

(4) *Typical mixtures* containing kaolinite, illite and quartz, but no mineral in sufficient concentration to permit classification as type 1 or 2. In this group both illite and kaolinite range from about 30–50 percent and the ratio of kaolinite to illite ranges from about 1:1 to about 1:2. Quartz accounts for the remainder of the bulk sample, except that as much as 5 percent of impurities may be present also. The d.t.a. curves of clays of this type show considerable variation.

CLAY MINERAL COMPOSITION

The method described by Murray (1954a) and others for determining the clay mineral ratios by means of x-ray spectrometer measurements has proved to be the only reproducible method. On two different occasions, using different instrumental settings and different portions of the specimens, the results were quite similar with respect to the ratios of illite to kaolinite. Such was not the case with the 4.25 Å line for quartz, however, so a reliable estimate of the quartz content apparently cannot be obtained by this method. The presence of quartz in the samples undoubtedly reduced the preferential orientation of mica and kaolinite flakes, but did not affect the ratios of (001) intensities of these minerals. A desirable consequence of the presence of quartz is the improvement of (11*l*), (0*kl*) and other reflections upon which differentiation of the mica polymorphs and the degree of crystallinity of the kaolinite are based.

In general, it appears that the kaolinite and illite in the underclays are probably of similar particle size, and thus particle size can be dismissed as a serious problem in comparing intensities from the respective (001) planes. The obvious exception for the bulk clay is the coarse-grained "muscovite" described above. This mica is not common, and in many clays it is rare or absent. Carr *et al.* (1953) noted that only 5 g. of coarse-grained hydrous mica was recovered from a 2 kilogram sample of the Yorkshire fireclay. It seems that the "muscovite" in the Ohio underclays is no more abundant. The effect of isomorphous substitution, particularly of Fe for Al in the illite, is probably not of considerable significance with respect to altering the intensity of the (001) reflection. The intensity of the (002) reflection of illites examined in this study is at least half that of the corresponding (001) illite reflection and nearly always approximates three-fourths of this intensity. Brindley (1951, p. 162) and others have shown that highly aluminous dioctahedral micas should produce first and second order basal reflections of comparable intensities, whereas for those high in iron the second order reflection should be weak or missing. Therefore the iron content of these illites is probably low.

Other effects, such as differences in the degree of crystallinity, which might cause departures from the theoretical ratios of reflecting powers of the (001) planes for illite and kaolinite, have been disregarded in our investigations. Should future studies show that the diffraction intensity ratio of 1:3, as used in our compilation, is not applicable to the Ohio clays, the data presented in table 1 can be modified accordingly. The ratios in table 1 do not indicate relative proportions of illite or kaolinite among different samples, but merely the relative amount of illite for each sample. The percent of quartz, which makes up the remaining bulk of the clays, is extremely variable from sample to sample; its ratios could not be satisfactorily determined by any method utilized in these investigations.

CORRELATION OF DATA

An attempt was made to correlate the data obtained from the d.t.a. and x-ray studies with the chemical analyses published by Stout *et al.* (1923) in order to determine quantitatively the mineral phases present. The problem was attacked first by calculating the percentages of the minerals present in the bulk clay from the chemical analysis by assuming ideal mineral compositions for pyrite, kaolinite, quartz, rutile and other minerals observed by microscopic examination, and an average composition for illite. The procedures were: (1) all sulfur and an equivalent amount of iron was alloted to pyrite; (2) the remaining Fe and equivalent inorganic carbon were calculated as siderite; (3) any remaining inorganic carbon was calculated as calcite, or less commonly, dolomite; (4) all Ca and Mg not assigned to calcite or dolomite was assumed to occur in illite; (5) illite was calculated on the assumption that it contains on the average 6.5 percent potash, sufficient Al, Mg and Fe to occupy octahedral positions, and Si for tetrahedral positions; (6) all remaining Al and equivalent Si were calculated as kaolinite; and (7) all remaining Si was taken as quartz. Calculations were then made of the predicted areas for the endotherms at about 600°C based on the contributions of the calculated minerals. The relatively minor contribution of quartz was necessarily disregarded. The predicted areas were then compared with those obtained experimentally. The correlations thus obtained were only fair, in general, and in some cases were poor. Inasmuch as the areas under d.t.a. inflections for most clay minerals depend upon composition, particle size, degree of crystallinity, etc. such data are semi-quantitative at best.

Other methods of calculating the mineral compositions of the clays were attempted and they were also compared with the d.t.a. results. The correlations were, likewise, not quantitative. The literature does not record successful quantitative analyses of similar clays involving three major minerals by thermographic methods; most determinations involve merely two minerals or are reports of data on prepared mixtures.

From the chemical analyses, particularly the K_2O+Na_2O contents in relationship to the Al_2O_3, a rough estimate of the ratio of illite to kaolinite can be obtained. These ratios are of the same order of magnitude as those listed in table 1. The estimation is based upon the fact that the alkalies undoubtedly occur in illite, whereas the aluminum, with the exception of that occupying octahedral mica positions, belongs to the kaolinite. Therefore, if the Al_2O_3 contents of several samples to be compared are the same, those with the greater alkali contents would be expected to have higher illite to kaolinite ratios. However, isomorphous substitutions in the micas, preclude accurate estimations.

DISCUSSION

The data presented in this paper indicate conclusively that the Ohio underclays are extremely variable in mineral composition. Variations in the ratios of the clay minerals (illite to kaolinite) occurs not only laterally within a particular stratum, but vertically within relatively short distances. The Lower Kittanning clay (also called "number 5" clay), one of the most important industrial clays in Ohio, has an illite to kaolinite average ratio of approximately 1.5. On the basis of the limited data of table 1, other less valuable clays show larger ratios.

That the ceramic properties of the bulk clay depend upon the mineral constituents has long been recognized. Illite and kaolinite have decidedly different ceramic properties. Numerous authors have discussed the influence of clay minerals on the ceramic properties and have also stressed the significance of particle size. A high proportion of illite in a clay would result in a correspondingly high percentage of alkali ions which act as fluxes at high temperatures and lower the fusion point of the mass. A high proportion of kaolinite results in a more

refractory clay. According to Carr *et al.* (1952) the fine-grained illite in some Yorkshire clays contributes a large firing shrinkage and little after-contraction, whereas coarse-grained illite (probably similar to the "muscovite" described in this paper) does not strongly influence the firing shrinkage, but has a marked effect on the after-contraction. Others have shown that high-illite clays often fire to yellow or brown colors as a result of the presence of iron. Plasticity, as well as other properties, are also dependent upon the mineral composition, in addition to other factors.

The role of impurities, particularly quartz, pyrite and siderite are well known, but it is interesting to note the effect of pyrite in samples 402 and 468, and calcite in sample 453, which contain the largest concentrations of these impurities (table 1 and fig. 1). Stout *et al.* (1923) reported that these samples bloated and that 453 and 468 could probably be used for lightweight aggregate. It is now generally recognized that calcite and pyrite are sources of bloating gases; in the case of specimen 468, coal fragments may also contribute.

Several questions were not adequately resolved in the present investigations and are worthy of further consideration, as follows:

(1) Possible differences in structures and compositions of the two texturally distinctive micas that occur in the underclays. Mixed-layer types of clay minerals might be found as a consequence of further study.

(2) More information on the kaolinite might permit characterization of the very well crystallized and the poorly crystallized ("fireclay") types and thus indicate structural or compositional differences.

(3) The changes in clay mineral ratios in different size fractions might prove of practical interest in predicting firing properties.

(4) A reliable method for estimation of quartz has not been developed for application to mixtures of this sort.

The ability to determine the mineralogical composition, and consequently predict the usefulness, of a clay by x-ray and differential thermal anlaysis has been considered in some detail in the light of experience with chemically analyzed Ohio underclays. Although these methods contribute valuable increments of information, they do not necessarily replace the petrographic microscope, and its use should not be abandoned.

SUMMARY

Examination of 42 samples of Pennsylvanian underclays of Ohio has indicated that they are composed predominantly of kaolinite, at least one micaceous constituent, and quartz.

From the x-ray diffraction data it is feasible to establish semi-quantitative ratios for illite to kaolinite that are reasonably consistent with the chemical analyses. Differential thermal analysis did not yield reliable estimates of the component minerals, but did contribute information of practical value. The underclays produced thermograms that can be classified according to four types, which are generally indicative of the kaolinite content and, in the case of type 3, indicated significant quantities of other material.

The mineralogical constituents of these underclays are correlated with known ceramic characteristics.

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Professor Wm. J. McCaughey provided the collection of analysed clays for which he had previously prepared petrographic descriptions (Stout *et al.*, 1923).

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This new text for lower division college students is "an integrative text" designed for a one-year course in general biology. It combines principles with type study; facts with social implications. The father-son authors state that, "a foundational biological education may best be acquired upon bases of plant-animal structure, ecology, and comparative physiology, leading to generalizations in terms of human social interrelationships." They have accomplished this in four steps. Part 1, Basic Biology, deals with broad concepts (history, evolution, protoplasm, development, ecology). Part 2, The Living World, is a review of various types of plants and animals from algae to mammals. Part 3, Comparative Biology, discusses nutrition, respiration, circulation, excretion, motion, reception and response, growth and reproduction in major plant and animal groups including man. Part 4, Social Biology, discusses disease, endocrines, inheritance, conservation, economic biology, and biology and society. Each chapter ends with "Questions and Problems for Group Discussion and Review" and a list of "Suggested Readings." An appendix outlines the plant and animal kingdoms to class or order, in most cases, thus relieving the text of a bulk of taxonomic names and presenting them in a unified and condensed form. There is a detailed index. The text is illustrated with 300 excellent figures, many of which are original, having been photographed or drawn by the two authors. Each figure illustrates a specific point and is referred to in the text.

RALPH W. DEXTER.

CHEMICAL COMPOSITION OF ANTONINIANI OF TRAJAN DECIUS, TREBONIANUS GALLUS, AND VALERIAN[1]

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The principal silver coin of the Roman republic and the early empire was the denarius. In the time of the republic and during the reign of the first few emperors this coin consistently contained a very high proportion of silver. Gradual debasement began at about the time of Nero (54–68 A. D.) and subsequently increased with slow acceleration, until at the time of Caracalla (211–217 A. D.) the silver content was down to about 60 percent. This emperor introduced a silver coin of new denomination known as the antoninianus, which was equal to 1½ denarii in weight but contained about the same proportion of silver as the denarius. The weight of silver in this new coin was about equal to that in the denarius of the middle of the first century A. D.

However, the same forces which caused the debasement of the denarius apparently continued to operate, for the antoninianus in turn began to be debased very soon after it was first issued. As is shown in table 1, this debasement at

TABLE 1

Weight and Fineness of Antoniniani Issued Prior to About the Middle of the Third Century A. D.

Emperor	Date	Average Weight	Average Silver Content	
		gm.	%	gm.
Caracalla	211–217	5.01	58.9	2.95
Elegabalus	218–222	5.10	42.8	2.18
Alexander Severus	222–235		None issued	
Maximinus	235–238		None issued	
Gordian III	238–244	4.42	41.7	1.84
Philip I	244–249	4.18	43.7	1.83
Trajan Decius	249–251	4.02	41.9	1.68

first took the form of a marked decrease in fineness, which was followed by a decrease in weight, the total result being a considerable decrease in the weight of silver in the coin over the period covered by the table. The data on the average weights shown in this table are those given by West (1941) and are derived from the weights of considerable numbers of coins. The data on the average fineness are based on relatively few coins and are largely derived from the results of fire assays first published by Rauch and republished by Bibra (1873). Apparently the proportion of silver in the antoninianus remained at almost a constant level from the time of the initial decrease up to about 250 A. D., but it must have dropped very rapidly between about 250 A.D. and 270 A.D., for the results of both fire assays and chemical analyses show that the proportions of silver in antoniniani issued in 270 A.D. and later are almost always less than 5 percent.

One purpose of the present investigation was to determine the exact time at which the second and final decline in the proportion of silver began to occur; the other was to make some careful chemical analyses of antoniniani since no really

[1]Paper presented at the Sixty-fifth Annual Meeting of the Ohio Academy of Science, Springfield, Ohio, April, 1956.

satisfactory analyses have been available. It is true that Bibra (1869, 1873) made a number of analyses of such coins, but the procedures he used were in various respects defective. His most satisfactory analyses are shown in table 2. Those excluded were made on corroded coins that contained considerable silver chloride, for such analyses are very probably not representative of the composition of the original coinage alloys. As with nearly all the chemical analyses of ancient alloys published by Bibra, the summations shown in the table total to exactly 100 percent, either because some one component was determined by difference or because the analytical results were prorated to obtain this exact summation. Aside from the errors introduced by this undesirable practice, the correctness of certain of his determinations may be questioned in other grounds. For example, most of his results for nickel are probably much too high, as is indicated not only by the method of determination he employed but by the results of the present investigation. However, it is likely that his results for silver are essentially correct.

TABLE 2

Analyses of Antoniniani by Bibra

Coin No.*	Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %	Zn %	Sb %
1	47.52	0.37	50.31	0.42	0.83	0.55	tr	——	——
2	21.43	1.53	75.86	0.11	0.46	0.30	0.31	——	——
3	17.31	——	81.83	tr	0.85	0.01	tr	——	——
4	12.14	tr	86.42	0.88	tr	0.10	0.44	——	0.02
5	6.01	tr	87.88	0.77	3.00	0.10	0.13	2.11	tr
6	5.02	——	92.20	0.42	0.51	0.37	0.33	1.15	——
7	4.89	——	93.64	0.50	0.27	0.08	0.62	tr	——
8	4.22	——	88.07	5.17	2.27	0.27	tr	——	——

*Attributions and Notes

No. 1. Philip I, 244–249 A.D. Bibra, 1873, p. 37.

No. 2. Valerian, 254–260 A.D. Bibra, 1873, p. 37.

Nos. 3 and 4. Posthumus, 259–267 A.D. Bibra, 1869, pp. 64–65. No. 4 also contained a trace of arsenic.

Nos. 5, 6 and 7, Gallienus, 260–268 A.D. Bibra, 1869, pp. 64–65. No. 5 contained a trace of cobalt, and Nos. 6 and 7 each a trace of sulfur.

No. 8. Claudius Gothicus, 268–270 A.D. Bibra, 1869, pp. 56–57. This coin also contained a trace of sulfur.

The figures for percentages of silver shown in tables 1 and 2 indicate clearly that the second marked decline in the fineness of the antoninianus must have begun sometime in the decade beginning with 249 A.D. However, because of the lack of chemical analyses of antoniniani of this period, the exact determination of this time has not been possible up to now. Therefore, twelve coins representative of the antoniniani issued by the principal rulers of this period were carefully analyzed. These coins, which were obtained by purchase, were in very good to very fine condition and could be accurately attributed to the rulers who issued them. By the method of analysis employed, which was essentially that outlined in a previous publication (Caley, 1950), all the principal components and all the usual minor components of the coinage alloys were accurately determined. The results are shown in table 3. Numbers 1a to 4a inclusive were coins of Trajan Decius (249–251 A.D.); numbers 1b to 4b inclusive were coins of Trebonianus Gallus (251–254 A.D.); and numbers 1c to 4c inclusive were coins of Valerian (254–260 A.D.). Each of the individual percentage figures for the components of these coins shown in the table is the average of two closely agreeing determina-

tions, and consequently each average percentage figure is based on eight determinations.

The sharp decline in the proportion of silver in the antoninianus in the period from 249 A.D. to 260 A.D. is clearly evident from both the individual and average figures shown in table 3. On the basis of these average figures this decline amounts to approximately 50 percent. However, by reason of the rather wide range of the individual figures for the coins of each emperor, it is obvious that a great many more analyses of coins of these emperors need to be made before exact average figures can be obtained and an exact figure given for the percentage decline in the proportion of silver. These rather wide variations in the proportion of silver in the coins of each emperor may be due merely to accidental variations in composition because of lack of proper control in minting, but this does not seem an adequate explanation since the fineness of Roman coins in general was controlled moderately well. A more likely explanation is that the proportion of silver in the coins not only decreased from reign to reign but also within each reign. In other words,

TABLE 3

Results of Analyses

Coin No.	Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %	Zn %	Total %
1a	42.21	0.33	56.18	0.11	0.43	0.08	0.08	0.11	99.53
2a	39.53	0.30	59.02	0.43	0.48	0.16	0.04	0.09	100.05
3a	38.33	0.27	59.00	1.40	0.64	0.11	0.04	0.11	99.90
4a	21.52	0.71	74.93	1.45	1.05	0.05	0.04	0.51	100.26
Av.	35.40	0.40	62.28	0.85	0.65	0.10	0.05	0.21	99.94
1b	36.80	0.17	61.31	0.65	0.50	0.10	0.03	0.05	99.61
2b	35.28	0.48	61.83	1.25	0.80	0.05	0.06	0.08	99.83
3b	29.96	0.22	65.94	2.63	1.07	0.03	0.05	0.09	99.99
4b	23.76	0.19	73.87	0.74	0.72	0.10	0.06	0.49	99.93
Av.	31.45	0.27	65.74	1.32	0.77	0.07	0.05	0.18	99.85
1c	24.44	0.24	73.44	0.78	0.75	0.08	0.07	0.08	99.88
2c	17.32	0.16	79.87	1.63	0.91	0.07	0.06	0.05	100.07
3c	15.10	0.15	80.87	2.74	1.02	0.13	0.06	0.04	100.11
4c	14.92	0.14	83.60	0.18	0.55	0.31	0.05	0.09	99.84
Av.	17.95	0.17	79.45	1.33	0.81	0.15	0.06	0.07	99.99

coins of higher fineness were issued earlier and those of lower fineness later in a given reign. However, the usual minor variations in fineness due to lack of very close control probably occurred also. If this explanation for the rather wide variations in the proportion of silver is substantially correct, chemical analysis would appear to offer a means of dating antoniniani of the emperors of this period more closely than is now possible from the inscriptions alone. Contrary to what seems to be indicated by the data of table 1, the second marked decline in the proportion of silver in the antoninianus had its beginning with the reign of Trajan Decius. Hence, with a possible error of a year one way or the other, the date of the beginning of this decline was 250 A.D.

The percentages of gold shown in table 3 are somewhat higher than might be expected in ancient silver coins of such low finenes. Though gold is nearly always present in ancient silver coins, the ratio of the percentage of gold to percentage of silver does not usually exceed about 0.005, and is very often less. But in these antoniniani as a whole this ratio is about 0.010. The actual ratios for each of the coins, as well as the several average ratios, are shown in table 4. The ratio for number 4a is unusually high and has not been included in computing the

averages since it is clearly atypical. If it were included, the overall average ratio would be 0.011 instead of the 0.009 shown in the table. Since there is a general tendency for the ratio of gold to silver to increase as the percentage of silver decreases and the percentage of copper increases, some of the gold in the coinage alloys was evidently introduced along with the copper or copper alloys that were used for debasement. A possible source of such gold could have been small proportions of gilded bronze or copper in scrap metal used for debasing the coinage alloys. Whether an unusually high ratio of gold to silver, such as was found for these coins, is characteristic of late Roman silver coins in general cannot be known until many additional careful analyses of such coins have been made.

TABLE 4

Ratios of Gold to Silver and of Nickel to Copper in the Coins Analyzed

Coin No.	$\frac{\% \text{ Au}}{\% \text{ Ag}}$	$\frac{\% \text{ Ni}}{\% \text{ Cu}}$
1a	0.008	0.0014
2a	0.008	0.0007
3a	0.007	0.0007
4a	[0.033]	0.0005
Av.	0.008	0.0008
1b	0.005	0.0005
2b	0.014	0.0010
3b	0.007	0.0008
4b	0.008	0.0008
Av.	0.009	0.0008
1c	0.010	0.0010
2c	0.009	0.0008
3c	0.010	0.0007
4c	0.009	0.0006
Av.	0.010	0.0008
Gen. Av.	0.009	0.0008

As may be seen from the data in table 3, copper was the principal metal used for debasing the coins. The percentages of tin, lead, and zinc are generally too low and the ratios of these to the percentages of copper too small to indicate that brass or bronze in the form of coins or in any other form was used exclusively for this debasement. Brass or bronze in small proportion may have been used, but the indications of the data are that impure copper was the principal material used for debasement. Probably this was added in the form of scrap metal or old worn coins from previous reigns, since the use of new metal for this purpose at this period seems unlikely.

The relationship that the percentages of nickel bear to the percentages of copper appears to be the only one among the percentages of the base metals that is in any way regular or systematic. As may be seen from table 4, the average ratio of these percentages for the coins of each emperor is the same. This indicates that the nickel is associated only with the copper in these coinage alloys. In all likelihood it was contained in the ores from which the copper was smelted. The actual percentages of nickel are very different from those found by Bibra (table 2) in his analyses of coins of this class.

In table 5 are listed the weights of the coins that were analyzed and their actual silver content in grams as computed from these weights and the corresponding

percentages of silver. It will be seen that the average weight of the coins of each of the three emperors is substantially the same. On the basis of proportion of silver the intrinsic value of these antoniniani for this period was reduced a little less than 50 percent (actually 49.4%) and on the basis of silver content by weight a little more than 50 percent (actually 51.7%). Evidently the intent was to decrease their value solely by decreasing the proportion of silver and not by decreasing their weight.

TABLE 5

Weight and Silver Content of Coins Analyzed

Emperor and Date		Weight gm.	Silver Content %	Silver Content gm.
Trajan Decius 249–251 A.D.		3.64	39.5	1.44
		3.61	42.2	1.52
		3.46	38.3	1.33
		3.12	21.5	0.67
	Av. =	3.46	35.4	1.24
Trebonianus Gallus 251–254 A.D.		3.86	23.8	0.92
		3.34	36.8	1.23
		3.18	35.3	1.12
		2.79	30.0	0.84
	Av. =	3.29	31.5	1.03
Valerian 254–260 A.D.		3.85	14.9	0.57
		3.48	24.4	0.85
		3.42	17.3	0.59
		2.68	15.1	0.40
	Av. =	3.36	17.9	0.60

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Caley, E. R. 1950. Notes on the chemical composition of Parthian coins with special reference to the drachms of Orodes I. Ohio Jour. Sci. 50: 107–120.

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Basic Mathematics for Science and Engineering. *P. G. Andres*, *H. J. Miser*, and *H. Reingold.* John Wiley and Sons, Inc., New York. 1955. vii+846 pp. $6.75.

This book is essentially a revision of *Basic Mathematics for Engineers* that was published in 1944. There appears to be no real reason for the addition of Science to the title.

For the usual engineering freshman mathematics course that covers elementary algebra, trigonometry, analytic geometry, and a touch of calculus this 3lb., 3 oz. book should prove to be sufficient.

There are—according to the publisher—650 worked out examples, and 7000 exercises. Half of the exercises have answers filed in 53 pages at the back of the book.

Tables include: Squares, Common Logarithms, Natural Trigonometric Functions (tenths of degrees), Logarithms of Trigonometric Functions (radians), Natural Trigonometric Functions (radians), Degrees to Radians, Common Constants, Symbols.

D. RANSOM WHITNEY.

A NEW SPECIES OF APHRICUS FROM CALIFORNIA (COLEOPTERA: ELATERIDAE)

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Aphricus lanei n. sp.

Male.—Narrow, elongate; dark brown, almost black; legs, antennae and mouth parts lighter; body and legs densely pubescent.

Head convex on vertex, front concave; surface densely finely punctured giving a rugose appearance; mandibles prominent; labrum connate with clypeus and in same plane; supra-antennal margin of frons continuous above labrum, finely carinate; antennae long, slender, reaching to about middle of elytra, ratio of lengths of segments 1 to 11, 8:4:6:10:11:12:12:12:14:13:14.

Pronotum longer than wide, widest near middle; sides converging posteriorly, sinuate near base, hind angles acute, somewhat divergent, with fine carina on side; disk convex, finely, densely punctured. Scutellum prominent, densely pubescent.

Aphricus lanei n. sp.
(Line equals 1 mm.).

Elytra at base wider than widest part of head or pronotum; sides subparallel near base then gradually converging to acutely rounded apices; surface with punctures of striae separated by less than their own diameters, punctures larger than those of pronotum, interspaces minutely punctured, pubescence dense.

Beneath with metasterum truncate anteriorly, mesocoxae separated, meso- and metathoracic suture distinct between mesocoxae, which are enclosed by meso- and metasternum; prothoracic sternopleural sutures not converging posteriorly. Legs slender, apex of each tibia with two spines.

Length 6.8 mm.; width 1.8 mm.

Holotype male and paratypes all collected in Lucerne Valley, San Bernardino Co., Calif. June 5, 1948 by D. J. and J. N. Knull. Holotype and paratypes in collection of author, paratypes in collection of M. C. Lane and The Ohio State University.

This species differs from *A. californicus* Lec. by being somewhat larger, darker in color and more pubescent. It lacks the apical carina on the fifth elytral interspace of *californicus*.

I take pleasure in naming this species for M. C. Lane, who has aided me greatly in my studies of the Elateridae.

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AQUATIC DIPTERA AS INDICATORS OF POLLUTION IN A MIDWESTERN STREAM

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A knowledge of the ecological requirements of aquatic organisms, especially the benthic forms, is of outstanding importance to biologists in determining the degree and extent of pollution in streams. An examination of bottom fauna serves to indicate conditions not only at the time of examination but also over considerable periods in the past. Those organisms having an annual life cycle will by their presence or absence indicate any unusual occurrence which took place during several previous months. Satisfactory use of aquatic organisms as indicators of pollution and self-purification of water is dependent upon a knowledge of the normal habitats of these organisms and their sensitivity to varying environmental factors such as pollution.

Among the aquatic invertebrates, insects such as the mayflies, stoneflies, and caddis flies are primarily restricted to clean water conditions. By comparison, forms such as the pulmonate snails, Tubificid worms, and certain species of leeches can more often be found under conditions where high organic and/or low oxygen content exist. Still other groups such as the Diptera, or true flies, are represented by forms which may be found in all types of stream habitats from the cleanest situation to the most polluted water.

Because aquatic Diptera are to be found in many different ecological niches in both clean and polluted water and many species are highly selective in their choice of habitat, they constitute one of the most important groups of indicator organisms. Year-round field studies of the ecology and distribution of the Diptera associated with the purification of organic wastes in streams were initiated on Lytle Creek in June, 1951. This creek, which is located about 45 miles northeast of Cincinnati, Ohio, is a tributary of the Little Miami River. Its drainage basin comprises 27 sq. miles, a third of which is contained within the city limits of Wilmington, Ohio, a city of 7,412 people in 1950.

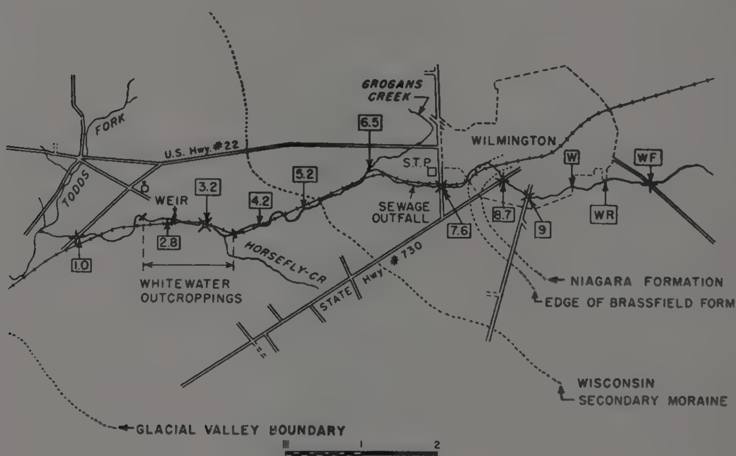
Lytle Creek is a permanent stream, approximately 11 miles long and has an average gradient of 25 ft./mile. It is 3 to 35 ft. wide during low water stages and varies in depth from a few inches in the riffles to more than 6 ft. in a few pools. Its natural flow is augmented, however, at a point about 7.3 miles above its junction with Todds Fork by the effluent from the Wilmington sewage treatment plant. Primary treatment including chemical precipitation is provided at this plant,[1] which treats an average of about 750,000 gallons of sewage per day. The sewerage is of the combined type, and the plant is overloaded during heavy rains which necessitates bypassing a large part of the total flow directly into the creek. During low flow stage in summer and autumn the sewage effluent comprises from 80 to 100 percent of the stream flow.

In any ecological study, such as this one, it is important to understand, as far as possible, all of the many factors which influence the distribution of the group of organisms being considered. The occurrence of certain species of Diptera in a given area may be determined by such factors as the direction of stream flow, and the type of bottom materials present. Because of the important influences which the physiography has in determining the fauna of a region, the geology of Lytle Creek is discussed briefly.

[1]Secondary treatment by means of activated sludge was initiated at this plant in 1954.

According to Austin (1930) Lytle Creek flows inside an ancient great valley filled in by the Illinoian Glacial invasion. The subsequent Wisconsin glaciations added a comparatively small amount of till. The stream has done very little cutting in its bed. The basic underlying rocks in the area, which by their dip, have determined the direction of stream flow from east to west, are of Ordovician Age and form the northward extension of the Cincinnati Anticline. There is evidence of a gentle subsidence to the north previous to the Illinoian Glacier with the result that many streams in the drainage basin flowed northward rather than to the south as they do today.

Lytle Creek rises in a secondary moraine of the Early Wisconsin Age, 2½ miles northeast of Wilmington, flowing through glacial till of that age over buried Silurian strata to Wilmington. This till near and through Wilmington contains great amounts of sand. About 9 miles above its mouth an ancient swamp or



LYTLE CREEK DRAINAGE BASIN

forest peat bed is crossed. This bed is decidedly acid (Austin, 1930). The creek continues beyond Wilmington to flow through till and sand, reaching outwash gravel terraces about 1 mile below the sewage treatment plant outfall. These terrace gravels are persistent for 1½ miles and may exert some influence on the 'purification' of the stream. At approximately 3 miles above its mouth, the stream cuts its valley deeply to an 'island' of bedrock of the Richmond group of the Ordovician. Just below this point the creek cuts off into glacial till, again leaving the bedrock, looping around for ⅛ mile to return to this rock, flowing on it until the formation ends about 2½ miles above the mouth. The remainder of the stream bed is glacial till with sand.

PROCEDURES

Twelve stations, representing all zones, were selected along the stream course for periodic sampling (fig. 1). Monthly, or more frequently, samples were taken at seven key stations for the determination of dissolved oxygen, pH, CO_2, methyl orange, and phenolpthalein alkalinity, and temperatures. Diurnal variations in

these physical-chemical factors during each of the seasons were determined by taking hourly samples at selected stations for 24-hour periods.

Quantitative bottom samples containing Diptera and other invertebrates were taken at monthly intervals at seven key stations in pools, runs, and riffles as part of a routine sampling program. A Surber square foot sampler was used in rifflle areas while an Ekman dredge was used in pools and runs. Marginal samples were taken by means of a handscreen (Needham) and special surface sampler (Tarzwell).

In addition to the specimens taken in the quantitative samples many Diptera were hand picked from specific micro-habitats throughout the stream. Attention was directed toward collecting as many different species of Diptera as possible, determining their habitat preferences, and correlating their distribution with the environmental variations which existed. Adult Diptera were also collected by sweeping vegetation with an insect net and by attracting them to a bright light at night.

The larvae and pupae collected during these reconnaissance studies were brought back to the laboratory alive and individually reared where possible. After emerging, the adults were chloroformed and preserved with their exuviae in vials of 75 percent ethyl alcohol. Some larvae and pupae were also killed and similarly preserved for future study and the correlation of larvae with the adults.

Keys and descriptions by Johannsen, Townes, and other workers were used for identification. Nearly all determinations of adult specimens were checked by Dr. W. W. Wirth of the U. S. National Museum.

RESULTS

Physical-Chemical Data. The Lytle Creek studies revealed that during the summer months when flows were low, septic, recovery, and clean water zones were distinct. From May to November each year variations in dissolved oxygen were at a maximum, and extensive oxygen depletion was characteristic of the two mile section below the sewage treatment plant outfall. During the winter months higher flows and lower temperatures resulted in the life (pollutional) zones changing their location and extent. During the period, December to April, natural purification proceeded at a slower rate, wastes were carried further downstream, and dissolved oxygen was abundant throughout the stream.

Daily maximum and minimum dissolved oxygen values recorded during four representative sampling runs have been shown graphically by Tarzwell and Gaufin (1953). Extreme variations in other important environmental factors affecting the biota in the stream are shown in table 1. Seasonal variations in these different factors throughout the stream have been discussed in detail by Gaufin and Tarzwell in previous papers (1952, 1955).

Biological Data. In addition to the superfamily Tipuloidea, 10 familes of Diptera were collected in Lytle Creek or its tributaries. Of these, 3 families, Psychodidae, Dixidae, and Ephydridae, occurred so rarely as to be of little importance in this study. The other seven, Culicidae, Chironomidae, Heleidae, Simuliidae, Stratiomyidae, Syrphidae, and Tabanidae, were taken on many occasions in various sections of the stream. Because of the variety of species and habits presented and their frequent appearance, the Chironomidae and Simuliidae were especially singled out for intensive consideration as the research progressed.

A total of 94 species of Diptera were collected during the course of this study. By means of their distribution in the stream it is possible to classify them into three categories; first, the pollutional forms, or those able to survive low oxygen and/or a high content of organic materials, second, the facultative or tolerant forms which can live under a wide range of conditions; and third, those forms

which require clean waters with abundant dissolved oxygen. A list of the species collected, the location where they were taken, and the pollutional status of the area in which each occurred are given in table 2.

Very few of the larvae and pupae of Tipuloidea can be identified to species with any degree of certainty. In addition, many species develop in moist soil as well as in truly aquatic habitats, and, therefore, many of the adults that may be taken along a stream may have emerged from habitats other than the stream itself. Unless the larvae are individually reared it is thus almost impossible to identify them with certainty. Because of these taxonomic difficulties and a lack of personnel the superfamily Tipuloidea was largely ignored in this study. However, of the seven species taken all occurred in clean water areas only.

TABLE 1

Extreme physical and chemical variations
Lytle Creek 1949–1952

		Stations									
		7.6 Clean Water Zone		6.5 Septic Zone		5.2 Recovery Zone		2.8 Lower Recovery and/or Clean Water Zone		1.0 Clean Water Zone	
Water Temperature	Max.	79°F	8/15/50	80°F	1/8–15/50	81°F	8/15/50	91°F	7/22/52	82°F	7/22/52
	Min.	32°F	12/6–7/49	39°F	12/6–7/49	32°F	12/6–7/49	32°F	12/6–7/49	32°F	12/6–7/49
B.O.D. (5 day) p.p.m.	Max.	2.6	3/14–16/50	82	8/15–18/50	42	12/6–13/49	13.5	12/6–13/49	6.4	12/6–13/49
	Min.	1.2	9/28–29/50	27	9/28–29/50	3.7	9/28–29/50	1.8	9/28–29/50	1.2	9/28–29/50
pH	Max.	8.3	2/25–26/52	8.2	2/25–26/52	8.4	7/26/51	9.1	5/16/51	8.6	7/26/51
	Min.	7.3	7/11–13/50	7.2	8/15/51	7.5	8/22–23/51	7.5	8/22–23/51	7.7	12/6–13/49
Total Alkalinity (as $CaCO_3$ in p.p.m.)	Max.	270	9/28–29/50	306	7/26/51	309	12/6–13/49	310	12/6–13/49	270	9/28–29/50
	Min.	185	3/14–16/50	222	11/28/51	216	3/22/51	223	3/22/51	169	12/6–13/49
Total Phosphate (p.p.m. PO_4	Max.	1.59	12/6–13/49	26.2	12/6–13/49	17.5	12/6–13/49	12.5	12/6–13/49	3.11	12/6–13/49
	Min.	0.55	8/15–18/50	4.0	9/28–29/50	2.4	9/28–29/50	2.3	9/28–29/50	1.32	9/28–29/50
Total Nitrate (TKN-N p.p.m.)	Max.	6.9	9/28–29/50	38.0	12/6–13/49	32.0	12/6–13/49	43.0	9/28–29/50	7.2	12/6–13/49
	Min.	0.04	3/14–16/50	10.0	9/28–29/50	6.9	9/28–29/50	0.95	3/14–16/50	0.45	3/14–16/50
Volume (c.f.s.)	Max.							100+	3/1951		
	Min.							1.0	8/1950		

Only one specimen of Dixidae, *Paradixa* sp., was collected, that being taken in June 1951, in marginal vegetation at Station 2.8 in the lower recovery zone. The family Psychodidae was represented by 2 genera, *Telmatoscopus* and *Psychoda*, and 4 species. Larvae of the first mentioned genus were found only under clean water conditions while the species of *Psychoda* taken were confined to the septic zone and zone of recovery. The immature stages of this genus are often found in the surface film of foul water, in sewage, and in wet, decaying, organic matter. One of the species found in Lytle Creek, *Psychoda schizura*, was also present in large numbers in the filter beds of the Dayton, Ohio, sewage treatment plant. Another family, Ephydridae, which occurred infrequently, but always where there was considerable decaying organic matter, deserves special mention because of the unusual habitats frequented. The larvae of one genus, *Teichomyza*, are found regularly in urine. Larvae and puparia of *Ephydra gracilis* occur in large numbers in the Great Salt Lake, Utah, where the dissolved oxygen content is frequently less than 1.0 p.p.m. and the salt content reaches 25 percent.

TABLE 2

Distribution of Diptera in Lytle Creek

Species	Stations and Bottom Type*								
	1	2.8	Horsefly Creek	5.2	6.5	Grogan's Creek	8.7	9	W
	Clean water sand & glacial till	End of rec. zone Ord. shaly lime-stone	Clean water sand to Ord.-shale	Rec. zone Poll. glacial gravel	Poll. zone glacial gravel	Clean water glacial till & sand	Clean water glacial till & sand	Clean water sand	Clean water glacial till
1. *Superfamily Tipuloidea*									
Pseudolimnophila luteipennis Alexander									F
Pilaria (Sintenis) sp. indet.									F
Tipula caloptera	F						F		
Tipula abdominalis (Say)			C				C		
Tipula cf. tricolor gr.	F								
Tipula cf. furca	F								F
Hexatoma cinera	F								F
2. *Family Psychodidae*									
Psychoda alternata (Say)				F	F				
Psychoda larva Johannseni *A*				F	F				
Psychoda schizura? (Fullaway)				F	F				
Telmatoscopus Eaton sp. indet.							F		
3. *Family Culicidae*									
(a) Subfamily Culicinae									
Culex pipiens L.		F	F	C	N	F	F	F	F
Anopheles punctipennis (Say)	F	F							F
(b) Subfamily Chaoborinae									
Chaoborus punctipennis (Say)	C								
4. *Family Dixidae*									
Paradixa Tonnoir sp.		F							
5. *Family Heleidae*									
Bezzia glabra (Coquillett)	F	F	F		F	F			F
Stilobezzia antennalis (Coquillett)				F	F	F			F
Heleidae, gen, et spp. indet.	F	F	F	F	F	F	F		F
6. *Family Chironomidae*									
(a) Subfamily Diamesinae									
Diamesa nivoriunda (Fitch)		F				F	F		F
(b) Subfamily Hydrobaeninae									
Hydrobaeninae gen. et spp. indet.	F			F	F				
Corynoneura scutellata Winnertz							F		
Corynoneura (Thienamanniella) Winnertz LC-72							F		
Hydrobaenus Fries sp. indet.		F				F	F		F
Hydrobaenus LC-81									C
Hydrobaenus LC-88									C
Hydrobaenus LC-98									C
Hydrobaenus (Psectrocladius) sp.		F				F			
Cricotopus absurdus Joh.		F							
Cricotopus bicinctus (Meigen)	C	N	N	F		F	C		C
Cricotopus exilis Joh.		C							
Cricotopus politus (Coquillet)	C	C	C			C	C		C
Cricotopus tricinctus (Meigen)	C	N	C				C		C
Cricotopus trifasciatus (Panzer)	C	N	C	F			C		C
Cricotopus LC-64		C	C						
Cricotopus LC-98							C		
Cricotopus sp. indet. (light adults)	C	C	C						C
Cricotopus sp. indet. (dark adults)	C	C	C						C
(c) Subfamily Pelopiinae									
Pentaneura carnea (Fabricius)		F		F			F		F
Pentaneura illinoensis (Malloch)		C	F						
Pentaneura melanops (Wiedemann)	C	C	C	C	C	C	C		C

TABLE 2 (*Continued*)

Species	Stations and Bottom Type* 1	2.8	Horsefly Creek	5.2	6.5	Grogan's Creek	8.7	9	W •
	Clean water sand & glacial till	End of rec. zone Ord. shaly lime-stone	Clean water sand to Ord.–shale	Rec. zone Poll. glacial gravel	Poll. zone glacial gravel	Clean water glacial till & sand	Clean water glacial till & sand	Clean water sand	Clean water glacial till
Pentaneura vitellina (Kieffer)									F
Pentaneura sp. indet.	F	F							F
Anatopynia dyari (Coquillett)	C	C	C	C	C	C	C	C	C
Anatopynia sp. indet.				F					
Pelopia stellata (Coquillett)	C	C		C	C	C	C		C
Pelopia punctipennis? Meigen	F	F		F			F		
Procladius culiciformis (L)		C							
Procladius LC-18	F	C		F		F	F		
Clinotanypus caliginosus	F								
Clinotanypus (pupal exuviae, indet)		F							
Coelotanypus concinnus (Coquillett)		C				C	F		F
(d) Subfamily Chironominae									
Calopsectra johannseni (Bause)		C							
Calopsectra neoflavella (Malloch)	C	C	C				C		C
Calopsectra nigripilus (Joh.)							C		C
Calopsectra LC-7	C	C					C		C
Calopsectra, sp. indet.	F								
Pseudochironomus richardsoni Malloch	F	F					F		
Polypedilum illinoense (Malloch)	F	N	N						
Polypedilum vibex? Townes		F							
Polypedilum fallax Joh.				C			C		
Polypedilum LC-15		F		F		F	F		F
Polypedilum sp. indet.	F			F		F			F
Tanytarsus LC-61							F		
Endochironomus nigricans Joh.		F					F		C
Xenochironomus scopula Townes		F							C
Cryptochironomus fulvus Joh.							F		F
Cryptochironomus LC-55	F	F	F	F		F	F		F
Chironomus neomodestus ? Malloch	F	C	F	F			F		F
Chironomus dux Joh.		F							F
Chironomus decorus Joh.	C	N	C	C	C	C	C		F
Chironomus riparius Meigen		F		N	N		F		F
Chironomus LC-26									
Chironomus LC-100		F							
Glyptotendipes lobiferus (Say)	F	F					F		
Glyptotendipes LC-31		F		C	C		F		
Harnischia tenuicaudata (Malloch)									F
Genus Incertus Mallochi D		F							
Microtendipes pedellus (DeGeer)	F	F					C		F
Paratendipes albimanus (Meigen)		F					F		
Stictochironomus varius Townes	F	F	C	F		C	N	N	N
Stenochironomus macateei (Malloch)		F							
7. *Family Simuliidae*									
Prosimulium johannseni (Hart)							F		
Simulium vittatum Zetterstedt	N	N	N	F			F		F
Simulium venustrum (Say)							F		F
Cnephia pecuarum (Riley)							F		
8. *Family Tabanidae*									
Tabanus atratus Fabricius	F		F	F	F	F			
Tabanus stygius Say	F		F	F	F				
Tabanus benedictus ? Whitney					F				
Tabanus giganteus DeGeer			F						
Tabanus lineola ? Fabricius					F				
Tabanus variegatus Fabricius			F						
Tabanus sp. indet.	F	F					F		F

Table 2 (*Continued*)

Species	Stations and Bottom Type* 1	2.8	Horsefly Creek	5.2	6.5	Grogan's Creek	8.7	9	W
	Clean water sand & glacial till	End of rec.zone Ord. shaly lime-stone	Clean water sand to Ord.-shale	Rec. zone Poll. glacial gravel	Poll. zone glacial gravel	Clean water glacial till & sand	Clean water glacial till & sand	Clean water sand	Clean water glacial till
9. *Family Stratiomyidae*									
Odontomyia cincta		F		F	F				
Stratiomys meigeni		C		C	C				
Stratiomys discalis				F	F				
10. *Family Syrphidae*									
Eristalis aeneus Fabricius					F				
Eristalis bastardi Macquart		F		C	N				
Eristalis brousi Williston					F				
Syrphus americanus Weidemann				F					
Chysogaster pulchella (Williston)				F					
Chilosia prima ? (Hunter)				F					
11. *Family Ephydridae*									
Brachydeutera argentata				F	F				

*Prefix LC before a number means the larva specimen is unidentifiable from available descriptions or keys and is found in Lytle Creek Basin.

F = Few, occasional specimen to 2 per square yard

C = Common, 3–50 per square yard

N = Numerous, 51 or over per square yard

As shown in table 2, the larvae of those species which can utilize atmospheric oxygen directly were all unaffected by low dissolved oxygen concentrations in the stream and occurred frequently in large numbers in the septic and recovery zones. The members of the families Culicidae, Syrphidae, and Stratiomyidae have special adaptations for obtaining oxygen from the surface, such as the terminal siphons of the mosquito and the "rat-tails" of the rattail maggot. Because of these adaptations, depletion of dissolved oxygen did not serve as a barrier to the distribution of these forms. Limited numbers of all species of these three families were also found in the clean water areas but they attained their greatest abundance in the polluted sections where food was abundant. The Tabanidae, the larvae of which enter and leave the water frequently or swim on the surface (Schwardt 1930), and the Heleidae, which are also reported to do so (Foote and Pratt 1953), were also found to be unaffected by pollution in the stream. The family Chironomidae (Tendipedidae) was represented by forms which display all degrees of habitat preference from the cleanest to the most polluted situation. The four species of Simuliidae that were taken were all confined to riffles or fast running water. Three of the species occurred only in the upper clean water sections of the stream. The fourth, *Simulium vittatum*, was found at all stations except in the septic zone. At Station 5.2 in the recovery zone it was often abundant in the riffles in a section of stream where the dissolved oxygen content frequently went below 1.0 p.p.m. at night.

Among the Chironomidae, *Chironomus riparius* was the only species taken regularly in the septic zone during the course of the study. It also occurred in large numbers in the recovery zone but was very rarely present in any clean water sections. By contrast, a closely similar species, *Chironomus decorus*, whose larvae are also red and possess ventral gills, occurred frequently in the clean water sections but was far less common in the polluted zones. These two species and a third

member of the group, *Chironomus tentans*, are frequently referred to in the literature as being positive indicators of organic pollution. All three species are often confused in the immature stages and are almost impossible to separate as larvae. In fact, Gaufin and Tarzwell (1952) considered *Chironomus tentans* rather than *Chironomus riparius* as being the characteristic species found in the septic and recovery zones of Lytle Creek.

Because these and other red-blooded Chironomids are commonly confused and associated only with habitats of high organic content a special effort was made to determine their taxonomic status and ecological adaptations. Specimens which were reared revealed that four of the species of red-blooded chironomids found in the stream, *Chironomus riparius* and *Chironomus decorus*, both of which possess 4 ventral gills, and *Stictochironomus varius* and *Microtendipes pedellus* which lack these gills, had such distinctly different habitat adaptations that they deserved considerable further study.

Of a total of 5,325 specimens of *Chironomus riparius* collected in 1951, all were taken from the polluted zones of the stream. By contrast, of the *Chironomus decorus* collected, 1,803 specimens were from clean water sections and 999 from the septic and recovery zone; while *Stictochironomus varius* produced 1,106 specimens in clean water and only 13 in the recovery zone. Of the 61 larvae of *Microtendipes pedellus* taken, all occurred in cleaner water areas. In addition to the latter two species, a number of others were largely, if not entirely, restricted to clean water areas.

Polypedilum illinoense, *Cricotopus absurdus*, and *Cricotopus politus* might be classified as clean water species since they were restricted to the clean water sections of the creek.

A difference in the response of several of the red-blooded species of chironomids to pollution was revealed by an experiment performed in the laboratory. Larvae of several species of Diptera clinging to stones in a rifflle and a pool at Station 5.2 below the mouth of a clean-water tributary, were collected and placed in well aerated jars of stream water from this station. At the time of collection (3:00 P.M.) the D.O. in the riffle was 6.5 p.p.m. while in the pool it was 5 p.p.m. The water had a characteristic sewage odor and the rocks were covered with a good growth of algae. Within 24 hours all larvae of *Stictochironomus varius*, *Calopsectra* sp. indet., and *Simulium vittatum*, and all but one of *Paratendipes* sp., all taken from the riffles, were dead. Half of the larvae of the *Chironomus decorus* group were alive and in good condition, some having pupated and emerged. The dead larvae of the *C. decorus* group were mostly *C. decorus*. Those which pupated and emerged and, most of those still living as larvae, were *C. riparius*.

Several species of Diptera appeared to be restricted by the rate of movement of the water, the type of substratum, or the kind of food present more than by the effects of pollution. The species of Stratiomyidae and Tabanidae, which were not dependent upon the amount of oxygen dissolved in the water, were found scattered throughout the drainage area according to the abundance of their particular food preference. *Stratiomys meigeni*, for example, was as abundant in mats of algae at Station 2.8 as at Station 6.5. *Tabanus atratus* and *Tabanus stygius* were scattered in distribution but were most common where there were cattle along the creek upon which the adults could feed. *Stictochironomus varius* was most common at Station 8.7 and in the intermittent tributaries of the main stream, where it was restricted almost entirely to a sandy stream bottom.

Another very important factor influencing the distribution of Diptera in Lytle Creek was the amount of precipitation. The normal rainfall at the Wilmington Station of the U. S. Weather Bureau for the 6-month period of April through September is 24.79 in. The year 1950 was near normal in summer rainfall after a very wet winter. The years 1951 and 1952 had dry summers which decreased both the flow of Lytle Creek and the normal dilution of sewage. Some

species taken in pollution zones in 1950 were not found in 1951 and 1952. The number of specimens of some species taken in 1950 was greater than that of the same species taken in 1951 and 1952. This may have been caused by non-uniform sampling, however. Tarzwell and Palmer (1951) state that the amount and character of rainfall exerts a definite and important effect on the growth of algae in a stream. Patriarche and Ball (1949) found that an increase of algae in ponds was followed by a great rise in chironomid population. This same influence undoubtedly affected the chironomid distribution in Lytle Creek. Large numbers of larvae and pupae occurred in the stream wherever there were mats of algae.

The physiography and geological history of the region also exert an influence, but slightly appreciated so far, on the fauna of Lytle Creek and its reaction to sewage pollution. The beds of gravel found throughout the creek provide possible habitats for many species of Diptera as well as strata for the holdfasts of algal, fungal, or bacterial growth. Also the climate was cool throughout the interglacial periods in this region (Austin 1930). These factors may have been determinants of the present abundance of species such as *Stictochironomus varius*, which based upon its distribution, seems to be a species of northern or cool climates (Townes, 1945).

The Whitewater formation which forms the bedrock bottom for a short distance at Station 2.8 is of more than passing interest.

This particular formation is an isolated one, no other outcrop being found anywhere else along the creek. Further, on both sides of this outcrop, drilling has failed to reach other bedrock at 77 ft. below the surface (Austin, 1930). Lytle Creek has cut but little into this bedrock (about 2 ft.) although it is relatively soft; but where it has formed cascades and piled up broken and eroded fragments, special habitats have been formed which have been utilized to a surprising degree by different genera of the family Chironomidae. For example, the cascades provide habitat for a few species of *Cricotopus* which have spread over them in great numbers, to the exclusion of practically all other species. In an approximate square foot sample taken in the Cascades June 10, 1952, the following specimens were found:

A). Larvae preserved (killed)—	
Cricotopus bincinctus	853
Cricotopus trifasciatus group	73
Hydrobaeninae, indet. (prob. *Cricotopus*)	37
B). Emergences from larvae kept alive and placed in culture jars—	
Cricotopus absurdus	11
Cricotopus trincinctus	56
Critotopus trifasciatus	43
Cricotopus bicinctus	175
Cricotopus, sp. indet	13
Total of known specimens	1261

In a zone of glacial boulders and piled rock in this area the species predominating to the exclusion of practically all others are *Simulium vittatum* and *Polypedilum illinoense*, thus demonstrating that in any given section the type of bottom may be very important in determining the type of fauna which is present.

DISCUSSION

As has been previously mentioned, the aquatic Diptera of Lytle Creek can be grouped into three categories relative to their pollutional responses—those found only in cleaner water, those usually found in polluted waters, and those which appear to show no preference for either polluted or clean water. In using these data for determining the degree of pollution or its presence or absence in streams,

consideration must be given to the physiology of the insects themselves, their relationship to the geology of the region, and to other environmental factors. These considerations are essential because there is a difference in habitat preference between the species, genera, families, and even suborders. All aquatic insects secure oxygen in one or more of three ways; directly from the atmosphere, by absorption of dissolved oxygen from the surrounding water, or by absorption of free oxygen from the aerenchyma of aquatic Tracheophytes which they puncture (Edwards, 1953a, b). Some of the species of Chironomidae are apparently able to carry on respiration even in oxygen depleted streams for a relatively long period of time (Walshe, 1950, 1951).

All of the "air-breathers" possess integuments which are practically impervious to water and salts. On the other hand, larvae of the Chironomidae and Simuliidae absorb dissolved oxygen from the surrounding water through the integument. In the pupae of these families it has been shown that the so-called thoracic respiratory organs are not used to extract dissolved oxygen from water. In those of the Simuliidae, however, the internal structure of these organs suggests possible adaptation for atmospheric absorption (Wigglesworth 1939). The direct air-breathers are equipped with siphons, open "trumpets," or tubes to maintain frequent contact of the tracheal system with atmospheric oxygen. Because the direct air-breathers are not dependent upon dissolved oxygen the lack of such oxygen, which is usually concomitant with zones of high organic pollution, does not deter them from utilizing these waters as habitats. Such conditions are advantageous for these organisms because food is plentiful and enemies and competition are restricted by the low oxygen supply. For example, the *Psychoda* population of sewage plant trickling filters is large and mosquito larvae and pupae occur in great numbers in septic zones. As many as 20,000 *Culex pipiens* larvae have been taken in a square foot marginal sample at Station 6.5.

Generally, the larvae and pupae of the air-breathing aquatic Diptera show an oxygen consumption that is independent of the dissolved oxygen content of the surrounding medium. This may result from morphological or physiological adaptations. The long "rat-tail" siphons of the Syrphidae, which may inhabit highly polluted waters, is a morphological adjustment of the air-breathing insect which makes it able to be completely independent of the oxygen of the surrounding water. Physiological adjustment is shown in several species of Chironomidae. The exact nature of this physiological adjustment is not known, but it has been found by various workers that some red Chironomidae containing erythrocruorin ("haemoglobin") can exist in the complete absence of dissolved oxygen for 30 to 120 days (Lindeman 1942). Walshe (1947b) also found that a colorless European species, *Prodiamesa* sp., survives under frequent low oxygen pressure tensions. The main advantage which "haemoglobin" seems to possess, is that it does not give up its 0_2 until a $p0_2$ of 7 mm. Hg. is reached; it enables fast recovery from a period of anoxia, and it is vital in the process of feeding (Walshe 1951, Wigglesworth 1939, Leitch 1916). There does not seem to be any ascribable function to haemoglobin when the dissolved oxygen is at zero p.p.m.

While many species of chironomids are adapted to low concentrations of dissolved oxygen and are able to withstand complete anoxia under laboratory tests for many days, our studies indicate that only some predatory species and those possessing ventral bloodgills persist in those areas of Lytle Creek which have continued low $p0_2$ or frequent oxygen depletion. In laboratory studies of *Chironomus plumosus*, Walshe (1947a) found that during a period of prolonged anoxia when the insect lived anaerobically the water surrounding it showed a great increase in the amount and number of organic acids. Wigglesworth (1939) believes that the ventral gills are organs of excretion; *i.e.*, that these allow the excape of lactic acid and other organic acids into the surrounding water medium, with the result that there is no "oxygen debt" since no lactic acid remains in

the system to be oxidized. While all larvae will die under prolonged anoxia, the length of time varying according to species, Walshe (1950, 1951) states that in certain instances death may be caused by factors other than lack of oxygen before asphyxiation takes place. The work of this investigator (Walshe 1951) indicates that starvation may be the direct cause of death in specimens surviving 30 days or more, because when the D.O. is lowered, feeding is abandoned in favor of undulatory efforts at aeration. She describes the process and states further that the larva when in great duress through anoxia, leaves its tube and will die after a period outside the tube if no dissolved oxygen is obtained. In such a situation feeding is abandoned completely and the respiratory efforts (undulating movements) are increased.

Miall (1912) and Miller (1941) postulate that predatory species probably rise to the surface of the water to obtain oxygen at the interface.

All these considerations of physiology are important because Lytle Creek contains 3 species of red-blooded Chironomidae each bearing ventral gills—*Chironomus decorus*, *C. riparius*, and *Glyptotendipes* LC-31. *Chironomus decorus* and *C. riparius* have 2 or more generations a year in Lytle Creek, with each generation having several broods. The second generation of *C. decorus*, which emerges when stream conditions are at their worst in September and October, has not been found in the septic zone, while the first generation was frequently collected. By comparison, both generations of *C. riparius* frequently occur in that area and larvae are very rarely taken at any other regularly sampled stations (4 larvae were collected over a period of 3 years at Station 2.8 and 3 larvae over the same period at Station 8.7

During a 24-hour study carried out in October 1952, at Station 2.8 where the water was 9 in. deep, it was found that the dissolved oxygen was consistently but slightly higher near the air-water interface, than that near the bottom. This finding may be important when it is considered that the "haemoglobin" of the red species is still ½ saturated with 0_2 when the oxygen tension (external oxygen pressure) = 4 mm. Hg. (Leitch, 1916) and that the predatory species move toward the surface at low $p0_2$ (Miller 1941). In comparison the haemoglobin of human blood begins to give up its 0_2 when the external $p0_2$ falls to 90 mm. Hg. and 50 percent is lost when $p0_2$ falls to 25 mm. Hg.

Another factor which may be limiting to the biota in a stream is the food supply. The food of aquatic Diptera may consist of materials orally ingested or dissolved materials absorbed through specialized structures elsewhere on the body. From the works of Wigglesworth (1939), Hers (1942), and others, it appears that the anal gills of Culicinae and Chironomidae and the rectal gills of Simuliidae and Corethrinae are used for the absorption of $C1^-$ from the surrounding water. Other foods, required for their metabolism are various, but in most instances the Chironomidae, Culicinae, and Simuliidae, consume microorganisms ranging from protozoa and algae to the small Arthropoda. Some Chironomidae and the Corethrinae are predators, feeding on the larvae of other members of the families. Still other Chironomidae are scavengers, among these is *Chironomus riparius*; Branch (1923) found this species appearing in great numbers in a sluiceway from a milk processing plant in New York. Due to the fact that some of the terrestrial Chironomid larvae of the subfamily Hydrobaeninae live in and feed on dung, it is not surprising to find some aquatic species adapted to feeding on sewage.

In controlled pond cultures, some fertilized with sheep manure and others unfertilized, Sadler (1935) found that *Chironomus tentans* ingests sheep manure in great quantities when it is available. Unfortunately, not enough work has been done on the larval food preferences of many Chironomid species to enable workers to use such information in determining habitat preferences. However, it is known that all aquatic larvae of insects must depend directly or indirectly

upon microorganisms such as bacteria, yeasts, and protozoa for the accessory factors such as vitamins which are essential for their growth.

While the availability and amount of food and oxygen were the most important factors determining the distribution of the majority of species of Diptera in various sections of the stream, other factors such as speed of current and bottom type should not be overlooked. For example, all four species of Simuliidae that were taken were confined to riffles or fast running water. Current can also limit the fauna as during the fall and winter months floods scour the bottom in some sections, carry away many Diptera, and intermix them with other populations downstream.

The nature of the stream bottom was also of considerable importance in limiting the distribution of Diptera in the stream. *Stictochironomus varius*, a common inhabitant of the upper clean water section and the intermittent tributaries, was restricted almost entirely to a sandy bottom. The bedrock cascades at Station 2.8 were inhabited by four species of *Cricotopus* to the exclusion of practically all other species. In a zone of glacial boulders and piled rock in this same area the predominate species were almost entirely *Simulium vittatum* and *Polypedilum illinoense*.

However, while all of these latter factors were important and should not be overlooked, the availability and amount of food and oxygen were the most important factors determining the distribution of Diptera in this stream.

SUMMARY AND CONCLUSIONS

1. A total of 94 species of Diptera representing 11 families and one superfamily were collected and identified from Lytle Creek or its tributaries during this study. These species were found in many different ecological niches in both clean and polluted sections of the stream, with many being highly selective in habitat.

2. All species with special adaptations for obtaining oxygen from the water surface such as the larvae of the families Culicidae, Syrphidae, and Stratiomyidae were unaffected by low dissolved oxygen concentrations in the stream and occurred frequently and in large numbers in the septic and recovery zones. Larvae of the tha families Tabanidae and Heleidae which can enter and leave the water frequently or swim on the surface were also found to be unaffected by pollution in the stream.

3. Representatives of the family Chironomidae were particularly adaptable to many different habitats in the stream, with a number of species showing a marked selection for specific ecological niches in each of the life zones. Because of their adaptability and selectivity of habitat they constituted the most important group of indicator organisms in Lytle Creek among the Diptera.

4. A number of ecological factors other than pollution were responsible for noticeable variations in the composition of the Diptera biota at different times and must be taken into account in interpreting the distribution of organisms in the stream. For example, normal decreases in the larval populations of certain species or the complete absence of others at certain times were caused by mass emergences of adults. Floods on occasion scoured out the bottom in some places intermixing the fauna or wiping it out completely.

5. The presence of *Chironomus riparius*, *Glyptotendipes* LC-31, *Eristalis bastardi*, and *Culex pipiens* in large numbers was very characteristic of the septic and recovery zones and their abundance in other similar streams may be interpreted as an indication of organic pollution.

6. The predatory chironomids had a wider range and greater adaptability to different environmental conditions than any other species, except *Chironomus decorus*, and because of their widespread distribution, their use as indicator organisms is distinctly limited. In addition *Anatopynia dyari*, *Pelopia stellata*,

Pentaneura melanops, *Pentaneura carnea*, and the families Heleidae and Tabanidae can be considered in this category.

7. A considerable difference in the pollutional tolerances of four red-blood chironomids was found to exist with *Chironomus riparius* being confined to the septic and recovery zones; *Stictochironomus varius* and *Microtendipes pedellus* to the clean water areas; and *Chironomus decorus* somewhat ubiquitous.

8. Species restricted to definite and narrow habitats constituted much better indicator organisms than those species adaptable to both clean water and polluted conditions. Because all of the species found in the septic and recovery zones were also found in limited numbers in the clean water areas, those species restricted to the latter areas have more value as indicators. On the basis of the Lytle Creek studies, *Polypedilum illinoense*, *Microtendipes pedellus*, *Coelotanypus concinnus*, *Endochironomus nigricans*, and possibly *Stictochironomus varius* and *Chironomus neomodestus* are positive indicators of an unpolluted habitat when they are present.

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Energy in the Future. *Palmer Cosslett Putnam.* D. Van Nostrand, New York. First Edition, 1953. x+556 pp. $12.75.

This is a study of the plausible demands for energy in the next fifty to one hundred years and the possible sources of this energy. The study was made under the auspices of the United States Atomic Energy Commission.

The author makes a historical study of population growth in an attempt to estimate the demand for energy in the future. His conclusion is that accurate predictions cannot be made. Thus he decides that the best we can do is estimate the maximum plausible demands and then consider the possible sources of energy to satisfy these demands. It is assumed that no catastrophy will befall the human race within the next century to halt the population rise.

The author assumes a rising standard of living based on a continued transition to an enlightened industrial-urban-farm pattern of economy which depnds on a constantly increasing use of low cost energy. He gives little attention to low grade or inaccessible (i.e. high cost) fuels. Also, the economic value of a source of energy depends upon the partiuclar use to which it is being put. For example, a solar energy device would not be economical for a small mobile unit such as an automobile.

The energy sources are divided into two categories:

(A) Capital energy which required the expenditure of some resource material such as a fossil fuel or a material which gives up energy in a nuclear raection.

(B) Income energy which includes such items as water power, solar heat collectors, wind power, photosynthesis, etc.

In 2000 the author concludes it is reasonable to assume 15 per cent of our total energy requirements will be satisfied by all "income" devices, 25 per cent by residual fossil fuels, and 60 per cent by nuclear fuels.

These implications are tremendous, and while quantitative estimates probably will be incorrect, this thought-provoking book points out problems which must be faced in the very near future.

Edward S. Foster, Jr.

THE COLLECTING OF AIRBORNE MICROORGANISMS

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During an investigation of the effects of two standard humidity control systems on airborne microorganisms an extensive study was made of the techniques for collecting airborne microorganisms from air streams and ventilated rooms. The results of the studies on collecting techniques as well as the data obtained for the two air conditioning facilities are presented herein.

The purpose of studying two different types of humidity control systems, namely Kathabar and a conventional system using refrigeration coils was to compare the effects of the two systems on the number of airborne microorganisms in treated areas. In the Kathabar, cooling coils are always dry. In conventional refrigeration systems the coils are wet when the air is being cooled but dry off when the refrigeration is shut off. The refrigeration coils are alternately wet and dry as the refrigeration compressor cycles on and off. Since bacteria and molds grow readily in moisture a study of the effect of drying off of the refrigerator coils was included as a part of this study.

A search has been underway for many years to find an ideal system of controlling airborne microorganisms in single rooms and buildings. The requirements for characterizing air sanitizing agents have been discussed by Kuehner (1952). Several systems have already been devised for removing airborne microorganisms, (Jennings, 1948; Berry, 1941) but the problems of control in occupied spaces is complicated by the fact that humans release microorganisms from the skin, hair, clothing and mucous membranes. The problem is to reduce "the number of pathogenic organisms in a given space to such a small amount that the chance of cross-infection becomes remote," (Jennings, 1949).

One of the factors in the control of airborne microorganisms is the control of humidity to reduce the growth of organisms on room surfaces and fixtures, (Nagy *et al.* 1954). The control of humidity is also important from the point of view of human comfort and productivity.

There are many industrial applications in which the control of both humidity and microorganisms is important, such as in the manufacture of foods, pharmaceuticals and beverages, (Lund, 1948; Shimwell, 1949). Both are important also in hospitals and operating rooms for the control of static electricity and cross infection, (Smith and Loosli, 1952). In research laboratories where disease-producing organisms are being utilized, the control of airborne microorganisms is absolutely essential, (Decker *et al.* 1954).

The evaluation of control systems can only be made if reliable and accurate methods of collection have been worked out.

MATERIALS AND METHODS

Collecting Criterion

During the preparation for these experiments it was realized that methods of sampling the air stream would have to be devised which would give a true sample of the air and hence, reliable and consistent data.

Three techniques were selected which were thought to meet these requirements. They have been designated the all-glass impinger technique, the Electrostatic Bacterial Air Sampler and the funnel impinger technique. The open Petri dish technique was used in the rooms being studied for comparison only.

Collecting with the all-glass impinger

One system of collecting samples consisted of all-glass impingers[1] connected to a Central Scientific "Hypervac" vacuum pump. The all-glass impinger had a critical orifice sized for 13.3 liters of air per min. so that the air flow was constant as long as the vacuum on the outlet of the impinger was 16.5 in. Hg or more. It is designed to collect organisms less than 20 μ in size. The sample tubes ranged from 6 mm. to 10 mm. inside diameter and were sized so that the sample velocity was approximately that of the air in the duct.

Sample tubes with 3 in. radius right angle bends were inserted through holes in the side of a duct, with a 4 in. leg pointed into the air stream. The other end of the sample tube was connected to the inlet of the all-glass impinger with intravenous rubber tubing. The outlet of the all-glass impinger was connected by vacuum tubing, copper tubing and a valve to a manifold, which was in turn connected to the vacuum pump. The vacuum pump had a capacity sufficient to maintain a vacuum of more than 16.5 in. Hg while pulling through 5 impingers. The test procedure was to install the sample tubes and impingers at as many as 5 stations and then start the vacuum pump. The air samples totaling 10 cu. ft. of air were bubbled through the impingers simultaneously for 21.2 min. At the end of this time, the pump was stopped, and the impingers were removed and stoppered with sterile cotton.

Previous to the taking of air samples, 25cc. of isotonic saline solution was placed in each of the impingers, and the impingers sealed, plugged with cotton and sterilized. Some loss of water occurred during the taking of the sample because of the lower humidity of the air flowing through the impinger. However, the final volume was used in calculating the concentration of microorganisms.

After the collection of air samples the impingers were again taken to the laboratory where the quantitative evaluation of microorganisms were performed. Aliquot portions were placed in sterile Petri dishes and mixed with freshly prepared Tryptose Blood Agar. After cooling, the petri dishes were inverted and incubated at 25°C and 37°C for 48 to 96 hr. The resultant colony growth was observed and counted. The tabulation was computed upon the aliquot portion and the average colony count.

Collecting with the Electrostatic Bacterial Air-Sampler

A Luckiesh-Holladay-Taylor (1946) Electrostatic Bacterial Air-Sampler duplex type, manufactured by the General Electric Company, was also used in the evaluation of air-borne microorganisms.

The sampler was connected to the air ducts by means of tubing and a funnel, and a total of 10 cu. ft. of air passed through the sampler.

Samples as taken from the sampler were then incubated 48 to 96 hr. at 25°C and 37°C and the colony counts recorded.

Collecting with Funnel Impinger

The funnel impinger method utilizes the impingment principle directly upon the surface of nutrient agar, Hollaender and Dalla Valle (1939). The air enters through the stem of a 45° glass funnel whose open end diameter is slightly smaller than that of a standard petri dish. The open end of the funnel was raised 3 mm. above the surface of the agar to permit the escape of air. The rate of air flow was metered at 1 cu. ft. per min. for 10 min.

The petri dishes containing Tryptose Blood Agar were then incubated at 25°C and 37°C for 48 to 96 hr., and the colony counts recorded.

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[1]Manufactured by the Ace Glass Co. Vineland, New Jersey.

Collecting with the Open Petri Dish

The "open dish" method is based on the impingment principle, wherein the heavier particles of dust, droplets and moisture to which microorganisms may be attached settle upon the surface layer of the nutrient agar. Freshly prepared Tryptose Blood Agar petri dishes were opened and exposed for fifteen minutes in the room air serviced by the air conditioning equipment. The petri dishes were then incubated at 25°C and 37°C for 48 to 96 hr. and the colony counts recorded.

Air Conditioning Equipment and Collecting Stations

Actual installations in two hotels in Toledo have been used for the experimental work. One hotel has a Kathabar installation for the control of humidity. The other hotel has refrigeration coils for the control of humidity in circulating air.

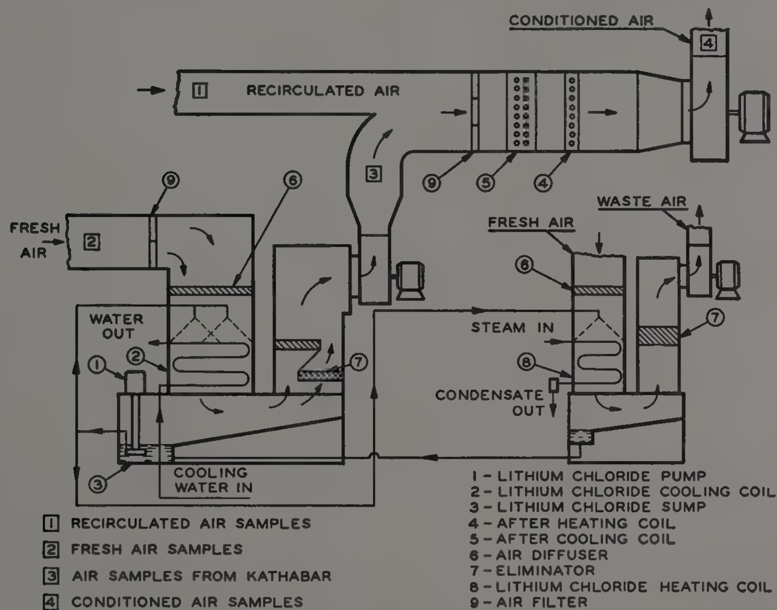

FIGURE 1. Kathabar equipment used in the experimental work.

The Kathabar system of humidity conditioning is a mechanical unit which brings air into contact with a lithium chloride brine, this solution removing or adding moisture in selective amounts. The operation is continuous and under automatic control.

Lithium chloride has a great moisture absorptive capacity, the amount of moisture removal from the air depending on the temperature of the brine. Regeneration of the solution is accomplished by heating to drive off the moisture absorbed, increasing the concentration of the solution.

Air conditioning equipment in hotel "A" consisting of a recirculated air system with fresh air make-up is diagrammed in figure 1. Fresh air is pulled through a bank of filters (9) thence through an air diffuser into a water cooled spray of lithium chloride solution. (1) (2) (3). Lithium chloride is removed from the air by an

eliminator (7). The air is then delivered to a plenum where it is mixed with the recirculated air from the room. The mixed air is then pulled by the main fan through a bank of filters, a direct expansion cooling coil (5) an after-heat coil (4) and delivered to the room. The lithium chloride regenerating equipment is shown on the right (6) (7) and (8).

Air volumes handled were 4,150 cfm of fresh air, and 5,600 cfm of recirculated air for a total circulation of 9,750 cfm.

Air samples were taken from the fresh air duct to the Kathabar, the duct leaving the Kathabar, the recirculated air duct, and the plenum after the heating coil as indicated on figure 1.

Air conditioning equipment in hotel "B" consisted of a recirculated air system with fresh air make-up essentially the same as in hotel "A" except that the fresh air was untreated. In this installation, the only fan was the main air fan, the proportion of fresh air to recirculated air being controlled by dampers. The fresh air was pulled through a door into a corridor, through filters in the corridor wall and into the equipment room which served as a fresh air plenum. It then entered a grille into the fresh air duct which terminated in a plenum where it mixed with the recirculated air. The mixed air then entered a conventional refrigerated air conditioning system. From this unit it entered the fan and was discharged into the room supply duct.

Air volumes handled were 1,735 cfm of fresh air and 2,685 cfm of recirculated air for a total circulation of 4,420 cfm.

Air samples in hotel "B" were taken from the fresh air duct, the return air duct, the mixed air plenum, the room supply duct.

RESULTS

The results of the samples of airborne microorganisms collected by three different techniques are presented in table 1. All samples were collected at the recirculated air duct of the Kathabar installation in hotel "A".

TABLE 1

Comparison of Sampling Methods

	All Glass Impinger	Electro-Static Air-Sampler	Funnel Impinger
Number of samples taken	23	36	19
Average no. of colonies 10^3 of air	224	221	26

These data indicate that the electro-static air sampler and the all glass impinger are about equally effective for the collection of air borne microorganisms but that the funnel impinger collects only about 11.5 percent as many organisms as do the other techniques.

During the period when other sampling methods were being checked in the recirculated air duct, samples were collected simultaneously by the open petri dish method from the room being treated. Of twenty-one samples taken during exposures of 15 min. each, the average number of microorganisms collected was 23. There can be no direct comparison because the volume of air from which the fall-out of microorganisms occurred is not known and the time of exposure was shorter than the exposure time by other methods. However the number collected was roughly 10 percent of the number collected by the all glass impinger and the electrostatic sampler in 10 cu. ft. of air. This indicates that the open petri dish technique is not adequate for quantitative measurements.

In view of the larger number of microorganisms collected by the all glass impinger all future experiments were with that equipment.

The next experiment was concerned with the number of microorganisms collected from two stations at hotel "A" designated as station 2 and 3 on figure 1. Thirty four samples were collected simultaneously at each station and the data are reported in table 2.

TABLE 2

Air Samples of Microorganisms Taken from Ducts at Hotel "A"

	Air to Kathabar Station 2 (fig. 1)	Air From Kathabar Station 3 (fig. 1)
Number of Samples Taken	34	34
Average no. of colonies 10 ft.³	525	9.7

Of the microorganisms entering the Kathabar only 1.8 percent remained in the air that leaves. 98.2 percent of the microorganisms were removed.

In the previous experiment the samples were collected only at the entrance and exit to the Kathabar. However, since only the fresh air is passed through the Kathabar a further check was made on the recirculated air and the mixture of recirculated air and Kathabar treated air, to determine whether the number of microorganisms is reduced in the air returned to the room as would be expected. Twenty-one samples were again taken simultaneously at four stations. The results are reported in table 3.

TABLE 3

Average Number of Airborne Microorganisms Collected at Four Stations Simultaneously. All Numbers Represent the Count for 10 Cu. Ft. of Air.

	Recirculated air Station 1 (fig. 1)	Fresh air to Kathabar Station 2 (fig. 1)	Air from Kathabar Station 3 (fig. 1)	Conditioned air after fan Station 4 (fig. 1)
Number of samples taken	21	21	21	21
Average number of colonies	223	220	1	119

These results show that the number of airborne microorganisms in the air returned to the room was reduced to approximately one half of the original room air count because the Kathabar had removed the airborne microorganisms.

Previous experiments had been concerned with total microorganisms which occurred in the sampling areas. Since the Kathabar proved to be an effective agent in removing microorganisms from the air, the effect of the equipment on removing pathogenic forms was also determined. Pathogens identified were of the following two types: Staphlococcus aureus and Streptococcus B hemolyticus (group A). The average counts obtained from 21 samples collected simultaneously at four stations are reported in table 4.

As explained earlier the main feature of Hotel "B" is dehumidification of room air by refrigerating the air, condensing out moisture on the cooling coils.

In Hotel "B" samples were collected from the air ducts while the refrigeration was on. In addition the refrigeration was turned off for as long as 1½ hr. to

collect samples at intervals in order to make counts of microorganisms from the air passing through the refrigerator coils as they warmed up and dried off. Swab samples were also taken directly from the coils.

The first experiments at Hotel "B" consisted of taking samples of air at 4 locations in the dehumidifying system. These results of 22 simultaneous collections are presented in table 5.

These results show an increase of 10.6 percent of the number of airborne microorganisms leaving the cooling coils as compared to the number in the return air, indicating an actual contamination of the air with airborne microorganisms.

TABLE 4

These results indicate that Airborne Pathogenic Microorganisms are removed by the Kathabar

	Recirculated air Station 1 (fig. 1)	Conditioned Air after fan Station 4 (fig. 1)	Fresh air to Kathabar Station 2 (fig. 1)	Air from Kathabar Station 3 (fig. 1)
Number of samples taken	21	21	21	21
Average No. of colonies	22	12	10	1 per 10 or 11 samples

TABLE 5

Air samples taken from ducts at Hotel "B"

	Fresh Air	Return Air	Air to Coils	Air from Coils
Number of samples taken	22	22	22	22
Average no. of colonies 10 ft.^{3}	809	800	817	885

Swab Tests

In order to further check the increase in the number of microorganisms in the air leaving the refrigerator coils swabbings were made upon the surface of the fins of the refrigeration coil.

One square inch area of fin surface swabbed with a moistened sterile swab averaged more than 10,000 colonies when plated out on Tryptose Blood Agar and incubated at 22°C and 37°C for 48 to 96 hr.

Growth and Release of Airborne Organism

Since it now seemed apparent that the air leaving the refrigeration coils at hotel B contains more airborne microorganisms than the air to the coils and since it was found that there are large numbers of microorganisms on the coils the next experiment was designed to collect organisms from the air while the refrigeration was on and at approximately 10 min. intervals for as much as 1½ hr. after shutdown.

The data are presented in figure 2. It is apparent from the data that microorganisms are released in increasing numbers from refrigerator coils as they dry up, reaching a peak at about 53 min. after the refrigeration is shut off; thereafter declining again.

As a final check on the all glass impinger an experiment was designed to check the efficiency of the equipment by placing two impingers in series. The average results of 13 experiments which were conducted at hotel "A", are presented in table 6. The counts reported represent the number of microorganisms in 10 cu. ft. of air.

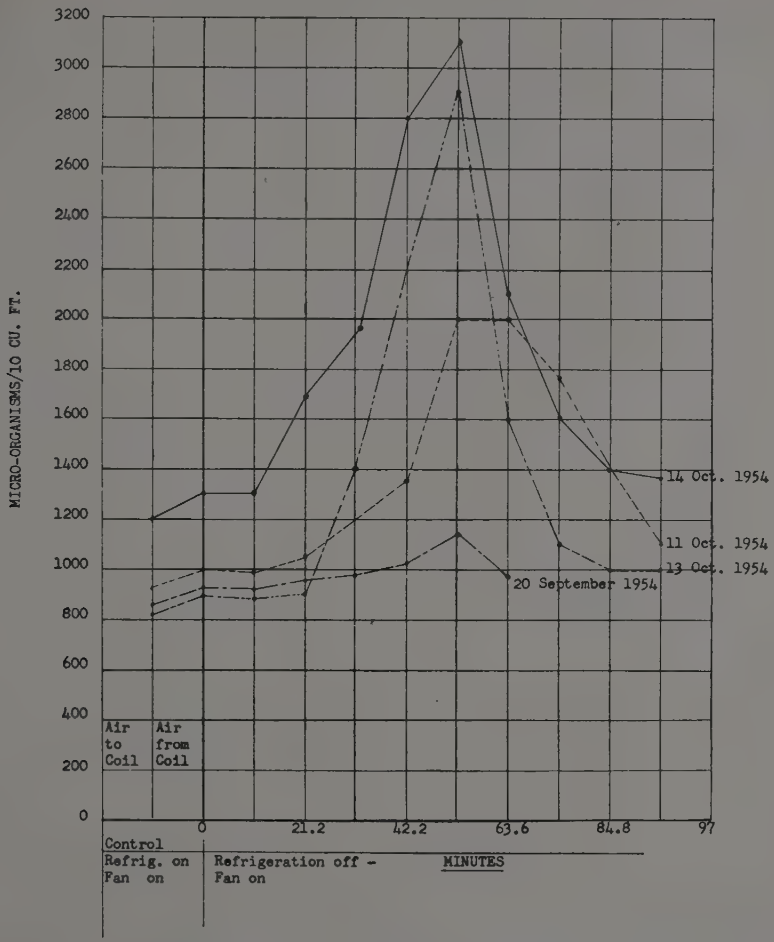

FIGURE 2. Graph showing numbers of airborne microorganisms collected from the air discharged through refrigerator coils at approximately 10 minute intervals after shut down.

TABLE 6

A comparison of the number of Airborne Microorganisms removed by two All-Glass Impingers placed in series

	First Sampler	Second Sampler	Percentage removed by Second Sampler
No. of tests	13	13	
Averages	232	2.4	1.03%

This table indicates that the all glass impinger is about 99 percent effective in the collection of airborne microorganisms.

DISCUSSION

One of the most serious considerations in modern research on airborne microorganisms is the technique of collecting samples. Very misleading results may be obtained unless efficient techniques are used. Therefore, comparison of results reported herein to other published data should be made only with full consideration of the collection technique employed.

The efficiency of the all glass impinger has been checked by operating two units in series. Despite the physical difficulties of obtaining a high vacuum on both impingers it was possible to pull the same air through both impingers. Since only about 1 percent as many organisms were collected from the second impinger as compared to the first it is assumed that the first impinger has an efficiency of about 99 percent. Corrections can therefore be made on data in accordance with that efficiency, although this was not done in the present report.

The efficiency of the Luckiesh-Holladay-Taylor Electrostatic Sampler was also checked against the all glass impinger by taking simultaneous samples by means of the two methods. The average of 37 samples collected by both methods showed almost identical results with the two methods.

The efficiency of a funnel impinger technique is only about one tenth the efficiency of the electrostatic and impinger techniques. It is therefore unwise to rely upon data collected by this method unless consideration is given to its efficiency. Depending on "fall-out" it cannot be expected to have the efficiency of more positive collection methods.

It is difficult to compare the efficiencies of various pieces of equipment which are available for the removing of airborne organisms. The results of our experiments with the all glass impinger would indicate that impingement in an aqueous solution is a very efficient method. This is the method used in the Kathabar. However, Decker *et al.* (1954) have reported 99 percent efficiency for glass fiber media. For complete safety from pathogenic forms, an air incinerator was recommended.

In many situations there is need for complete removal of microorganisms from the air. As Jennings points out, in other situations a high percentage of removal is all that is required. The Kathabar system as presently designed will remove about 97 percent of the organisms (as corrected for the efficiency of the collecting system) and is therefore satisfactory for those situations requiring only a high percentage of removal. No doubt the efficiency of the Kathabar could be increased by redesign and by the addition of a second lithium chloride solution wash.

Several advantages of the Kathabar system of control of airborne microorganisms became apparent during the investigation. First of all, it is an automatic system requiring a minimum of maintenance. Second, it is not necessary to decontaminate the system if used to collect pathogenic forms because they are contained within the lithium chloride solution which is bactericidal. Third, the machine also controls humidity which is essential to human comfort and moisture sensitive industrial processes as well as to the control of microorganisms.

The removal of moisture in an air conditioning system by refrigeration is not adequate for the control of airborne microorganisms. The refrigeration system which was studied in the investigation reported herein did not remove microorganisms. In fact, the bacteria increased in numbers on the cooling coils, and were later released into the room air when the refrigeration system cycled.

SUMMARY

The all glass impinger and the electrostatic air sampler were about equally effective in the collection of airborne microorganisms from air streams. The all glass impinger has an efficiency of about 99 percent. The electrostatic air sampler can then be presumed to have about the same efficiency.

Kathabar-treated air is relatively free of airborne organisms. This may be due to the impingement of organisms into the lithium chloride solution. The present data indicate that more than 97 percent of the organisms are removed by the Kathabar. The Kathabar was found to be as effective in the removal of airborne pathogenic microorganisms as in the removal of nonpathogenic forms.

Dehumidifying systems employing only refrigeration coils may increase the number of microorganisms in the air by providing on the refrigeration coils a suitable medium for the growth of microorganisms and their release into the air.

ACKNOWLEDGMENT

It is a pleasure to acknowledge the assistance of Leon Idoine, Marvin Rohrs, A. A. Fejer and Fred Johnson. The authors gratefully acknowledge the assistance of the Surface Combustion Corporation for sponsoring this project.

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Insect Pests of Farm, Garden and Orchard. *L. M. Peairs* and *R. H. Davidson.* John Wiley and Sons, Inc., New York. Fifth edition, 1956. viii+661 pp. $8.50.

The fifth edition of this economic entomology text comes to us at a most appropriate time. During the past ten years, there has been a veritable revolution in insect control with insecticides and it has been necessary to use technical papers or bulletins to keep pace with these advances. Now in one volume, Peairs and Davidson have assembled the last word in insect pest control for use by the entomologist and agricultural adviser. It is the opinion of this reviewer that we have now attained a period of relative stability in the recommendation of insecticides for our major insect pests and yet-to-be discovered insecticides will be slow to replace the toxicants included in this volume.

The authors include pertinent information on insects recently introduced or established as pests in this country in addition to providing the latest distribution of all important economic insects. Basic concepts dealing with insect morphology, metamorphosis and classification are presented in introductory chapters. Biological, mechanical and cultural control methods are presented in proper perspective.

The entomologist will find that some scientific names are not in accord with the approved list published in the December, 1955 Bulletin of the Entomological Society of America. The revision of scientific names is an ever continuing process which creates a source of error in textbooks regardless of publication date. Too often, a person will employ a scientific name used in a general text with the belief that presence in a "book" establishes authenticity.

James W. Apple.

The Honey-guides. *Herbert Friedmann.* United States National Museum Bulletin Number 208, Smithsonian Institution, Washington. 1955. xxxi+292 pp. $1.75, paper bound.

This is the museum's newest bulletin and is a monograph of a family of old-world birds. Dr. Friedmann discusses the systematics of the Family Indicatoridae, and reviews many of these birds' unusual habits. One new discovery is that the birds eat the beeswax instead of the honey, as was formally assumed.

Other interesting topics discussed are the guiding habit, mammalian symbionts, the antiquity and evolution of the guiding behavior, and the origin of cerophagy. One phase of the life history that will require more research is how the birds are able to digest the highly complex wax. The two theories brought forth in the paper were either the possibility of an undescribed enzyme or an unknown bacteria in the digestive tract.

In reviewing the taxonomy, Dr. Friedmann considers all eleven known species in the family. These species are distributed among four genera (*Indicator*, *Melichnentes*, *Melignomon*, and *Prodotiscus*). He also discusses the evolutionary trends of the family and the relationship to other families such as Capitonidae, Picidae, and other families in the superfamilies of Capitonoidea and Gabuloidea.

The bulletin is one of the finest examples of a monograph that the reviewer has seen. The monograph is made more complete by the excellent choice of plates, five of which are in color. All the known species of Indicatoridae are represented on these color plates, done by the well known artist, Walter A. Weber of the National Geographic Society.

John M. Condit

Climates in Miniature. *T. Bedford Franklin.* Philosophical Library, Inc., New York. 1955. 137 pp. 10 Figs. 11 Tables. $3.75.

T. Bedford Franklin is an English amateur gardener-naturalist who, for more than fifty years, has been keenly interested not only in the plants and animals of his gardens and nearby country-side, but also the immediate environments in which they occur. He has conducted numerous short-lasting, small experiments with simple equipment concerning various environmental factors, especially the temperature factor. The reader will find a good discussion of the dynamics of soil heating and cooling and how it varies with soils of different textures, colors, moisture contents, and with different mulches such as leaf litter, loose soil, ashes, manure, short turf and snow. Temperature data are also included of such items as rabbit burrows, mole runs, hedgehog hibernating quarters, compost heaps, and cranberry marshes. Other chapters include general discussions of the following in relation to the home-gardener: frost formation, humidity and dew, wind and shelters, light and shade, and cold frames. The book is written in non-technical, home-gardener style, and unfortunately contains numerous teleological "explanations". Also, the author without scientific botanical training attempts a discussion of the effects of numerous environmental factors on plant physico-chemical processes, as well as a discussion of the processes themselves, with the result that numerous statements are made which are partially or completely in error. This book is not designed as a text; no references are included.

G. E. Gilbert

General Biology. *Gordon Alexander.* Thomas Y. Crowell Company, New York. 1956. xiv+881 pp. $6.75.

This new textbook is a comprehensive presentation for a full year's course in general biology. By presenting a wealth of material through a wide range of topics the author makes it possible for a teacher to select the content and sequence he wishes in adapting the book to a great variety of teaching plans. This book combines classical emphasis on structure with modern emphasis on function. Biology of the frog and of man are featured throughout much of the book as types of vertebrate animals and are treated comparatively throughout. In addition to this extended comparative study of structure-function, other outstanding features are the modern treatment of taxonomy and ecology.

Part one deals with fundamental principles of biology; part two considers metabolism and irritability in vertebrates; part three is devoted to reproduction and development in vertebrates; part four is on metabolism and irritability in higher plants; while part five deals with reproduction and early development in higher plants. Part six is a unit on heredity; parts seven and eight are surveys of the animal and plant kingdoms; part nine is devoted to distribution and includes chapters on ecology and conservation; while the final unit, part ten, covers organic evolution

At the end of each chapter there is a summary and a list of review questions. There are approximately four hundred illustrations and a detailed index. This should be a successful text for college classes in introductory biology.

Ralph W. Dexter.

CONTACT ANGLES OF WATER ON LAMINATED PLASTICS AND THEIR RELATION TO RATE OF WATER ABSORPTION

JESSE H. DAY AND LOUIS SPERRY[1]

Department of Chemistry, Ohio University, Athens, Ohio

INTRODUCTION

Two important properties of any plastic material are the amount of water it absorbs and the rate of absorption since these will determine whether the material can be used where good dimensional stability or good electrical properties are required.

The standard water absorption tests are those of the American Society for Testing Materials (hereafter referred to as A.S.T.M.): test D–570–42 for 24 hour absorption, and test D–229–46 for total absorption. These involve the preparation of a special test piece and the weights of the piece before and after immersion in water. The water absorbed is expressed as percent by weight.

In this work, the contact angle of water on several plastic samples was measured to see whether there was any good relation between contact angle and the rate of water absorption or total water absorption. The point of interest is that contact angle measurements can be made quickly and easily with a minimum of equipment and do not require a standard sample. It might be noted that neither our tests nor the A.S.T.M. test measures ultimate water absorption. Our samples were still absorbing after 840 hours.

MATERIALS AND METHODS

The plastic samples used were commercial laminates prepared and donated by the Synthane Company.[2] Each sample was cleaned of mold lubricants and mold release agents by wet blasting and in our laboratories was washed with soap and then with alcohol and dried before use. The edges were sealed with lacquer so that absorption took place only through the surfaces. Water absorbed was measured by weighing. Five different compositions of laminates were used: 1. a melamine resin, with continuous filament woven glass; 2. a phenolic resin with fine weave cotton fabric; 3. phenolic resin with staple fiber nylon fabric; 4. phenolic resin plasticized with tung oil and laminated with paper; and 5. phenolic resin with paper.

Contact angles can be measured by a number of methods. The sessile drop method was not good for our purpose since the surface of a laminate is not completely homogeneous or smooth. A second method, which gives an average contact angle, is measuring the angle of a meniscus across the surface of a partly immersed plane sample. This second method was used in two modifications. In the first modification, called the tilting plate method, the sample is partly immersed in the water and then tilted until the surface of the water is perfectly flat at the line of contact. Thus, the angle of the sample is the contact angle. This measurement can be made precise, since a slit of light projected by a small slide projector can be reflected from the water surface onto a screen and the sample tilted until the slit image is straight.

The second modification, which was used most, was to immerse the plastic sample partly into the water, keeping the sample vertical. A shadowgraph is obtained by focusing a beam of light parallel to the water surface and by allowing the shadow image of the surface and the sample to strike a slow emulsion photo-

[1]This paper is taken in part from a thesis submitted by L. S. in partial fulfillment of the requirements for the M.S. degree at Ohio University, February, 1954.

[2]Synthane Corp., Oaks, Pennsylvania.

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graphic paper. This has the advantage of giving a permanent record. The angle of the meniscus is then measured with a protractor.

The angle measured by these methods was the advancing angle. The receding angle on these surfaces was less reproducible and very small, a hysteresis of 20 to 40 degrees not being unusual.

All water absorption tests were run on duplicate samples. They were in complete agreement. The contact angles were reproducible to about 3 or 4 degrees, and each reported angle is the average of 5 or more determinations on each sample.

RESULTS AND DISCUSSION

The main factor influencing the contact angle is the affinity of the surface for water. The factors influencing the rate of water absorption are the chemical nature of the plastic, the nature of the laminating filler, and the physical structure of the laminate, particularly with regard to the completeness of bonding between the plastic and the laminated material. One might expect the rate of water

TABLE 1

Rate of water absorption by laminated plastic samples

	Sample One*		Sample Two		Sample Three		Sample Four		Sample Five	
Hours	g./hr.	log+5	g./hr.	log+5	g./hr.	log+5	g./hr.	log+5	g./hr.	log+5
0.4	1.500	5.176	.096	3.982	.022	3.342	.0110	3.041	.0615	3.789
1.5	.155	4.190	.015	3.176	.002	2.301	.0027	2.431	.0200	3.301
3.5	.080	3.903	.001	3.041	.....	.....	.0030	2.477	.0170	3.230
6.5	.043	3.633	.....	.....	.0013	2.114	.0010	2.000	.0130	3.114
12.5	.020	3.301	.....	.....	.0010	2.000	.0009	1.954	.0095	2.978
25.5	.0093	2 968	.0017	2.230	.0013	2.114	.0010	2.000	......	.....
50	.0024	2.380	.0023	2.362	.0010	2.000	.0003	1.477	.....	.....
97	.0011	2.041	.0018	2.255	.0006	1.778	.0006	1.778	.0049	2.690
167	.0004	1.602	.00093	1.968	.0003	1.477	.0003	1.477	.0040	2.602
286	.....	.....	.00065	1.813	.0002	1.255	.0001	1.114	.0030	2.477
575	.0002	1.230	.00065	1.813	.0002	1.230	.0001	1.176	.0020	2.279
840	.0001	1.041	.00040	1.602	.....	.....	.0001	0.875	.0011	2.041

*Under each sample number, the first column is the number of grams of water absorbed per hour; the second column is the log of the first column plus five.

absorption to be related to the contact angle since both are determined by the affinity of the plastic for water. One might further expect that those samples which eventually absorb the most water would also be the fastest absorbers, but this is not always the case. The actual weight of the water absorbed, and the rates of absorption are listed in table 1.

The logarithm of the rate of water absorption plotted against time yields some important information (fig. 1). It is immediately obvious that there is a real relationship between the contact angle and the rate of absorption. The relation is not precise, but a more exact relation should be obtained for samples which are solid plastic with no filler.

The shape of these curves provides some information about the structure of the laminate. In general, each curve consists of three parts. The first part is the rapid drop in rate from a high value to one of about one-tenth the initial rate in the first hour or two. The samples with the highest initial rate drop the fastest. We attribute this to the physical structure of the laminate since it is most marked for the samples in which there is the poorest bonding between plastic and laminated material. Thus, we would expect a higher percentage of voids at the surfaces, and cracks at the surface between plastic and filler, which would take in water by capillary action. These voids would be filled in a short time.

The third portion of the curve is a virtually straight line, of much the same slope for samples of the same plastic, independent of filler. In this part of the curve we feel that the absorption is that of the plastic material itself. The fact that the rate is still highest for those samples which were initially highest merely means that the effective surface of the plastic material is larger, since it would include more surface about the voids.

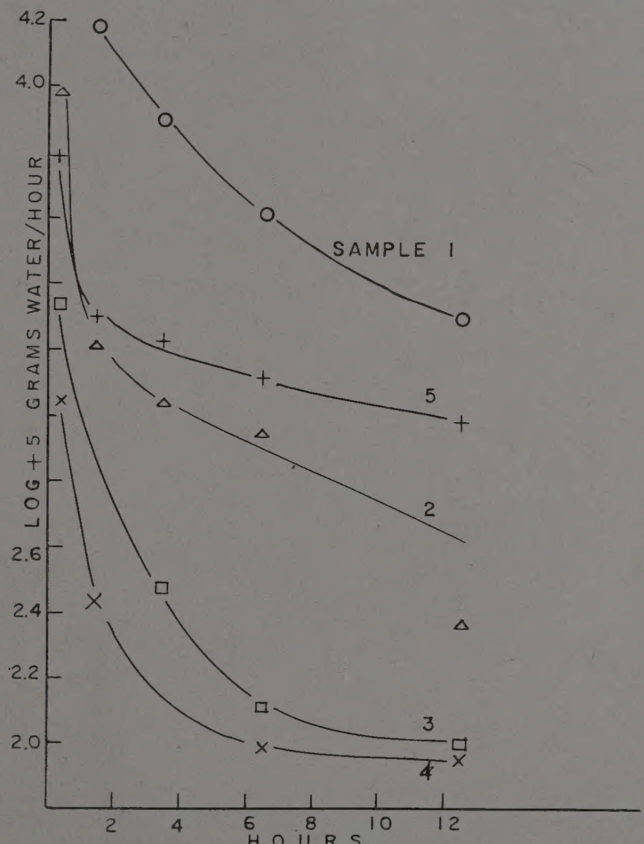

FIGURE 1. The log of the rate of water absorption in grams per hour, plotted as a function of time. 1. melamine resin with continuous filament woven glass. 2. phenolic resin with fine weave cotton fabric. 3. phenolic resin with staple fiber nylon fabric. 4. phenolic resin laminated with paper and plasticized with tung oil. 5. phenolic resin with paper.

The intermediate portion of the curve shows a transition period in which both mechanisms of absorption are taking place and the filler is being soaked. Thus, the transition for the melamine-glass laminate is sharp with little or no intermediate portion. This is explained by the fact that glass does not absorb. The transition is also relatively abrupt for the sample filled with nylon since the nylon and phenolic resin would absorb at about the same rate and total extent. The intermediate portion is most prolonged for the cellulose and paper filled samples, meaning

that these fillers are soaking faster than the plastic and finally becoming saturated, at which time we enter the third portion of the curve for these samples.

The sharp first portion of the curve lasts for less than an hour for the sample of contact angle 28 degrees, for one and a half hours for angles 41 to 46, and for about 5 or 6 hours for angles 53 to 58.

The melamine-glass laminate starts at the highest rate and drops off most rapidly. Probably there are more capillary voids, due to lack of complete bonding between glass and resin. This high initial rate drops off more rapidly than the initial rates for the other materials, but the actual rate for the melamine-glass laminate remains above the rates for the other samples, since the effective absorbing surface is greater due to the voids. For this same reason the rate drops more rapidly due to faster saturation of the resin.

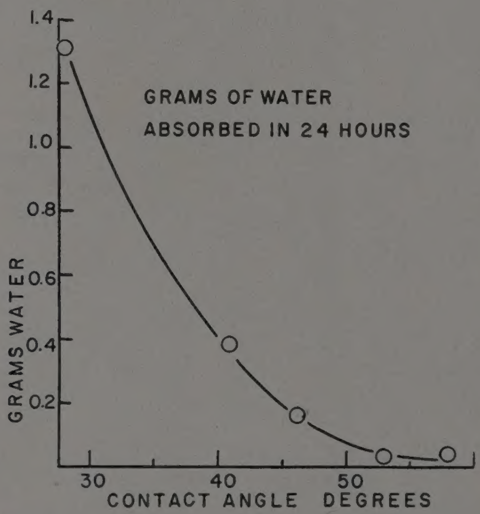

FIGURE 2. Grams of water absorbed in 24 hours plotted as a function of the contact angle of water on the plastic surfaces.

The phenolic-paper laminate and the phenolic-cotton sample yield curves which are similar in shape and slope, except that the phenolic-cotton curve drops off more rapidly in the period from two to 25 hours, but has the same slope thereafter. The difference must be due to the filler. Possibly the more continuous structure of the paper keeps the rate higher, but at 25 hours the decrease in the rate of the two is about equal, meaning we are dealing with diffusion into the resin in both cases.

The phenolic-nylon rate starts at a lower value and the slope of the rate changes more slowly, there being a less abrupt transition from capillary absorption to absorption by the material. This curve is probably more like that of a pure plastic since in this case the filler, nylon, is itself a plastic with roughly the same affinity for water as the phenolic resin.

The tung oil plasticized phenolic-paper sample is a separate case, but we might expect a less voided structure, and a plasticized paper, which would give a case most nearly like that of the phenolic-nylon sample.

Since the amount of water absorbed in a given time interval varies in a complex way with the thickness of the piece, similar data should be obtained for each thickness and a thickness versus rate curve found. The contact angles we measured and compared with the results of the 24 hour A.S.T.M. immersion test in figure 2. The correlation is evident. However, for the contact angle test to be used for the prediction of the water absorption rate, these data must be collected for a much larger number of samples. This paper can be considered only as indicating such a possibility.

Ultimate water absorption data from the manufacturer are compared with our data for 840 hours immersion in table 2.

TABLE 2

Ultimate water absorption expressed as percent by weight

Sample	Our data, 840 hours	Manufacturer's data
1	6.54	6.5
2	4.60	8.0
3	1.22	1.0
4	1.44	2.0
5	13.6	12.0

CONCLUSIONS

The logarithm of the rate of water absorption of five laminated plastic samples is a function which varies, within the limits of uncertainty of the contact angle measurement, with the contact angle of water on their surfaces, despite a considerable difference in the fillers used in the samples. The nature of the fillers probably contributes to absorption in four ways: (1) the number of capillary voids in the sample due to the type of filler, (2) the rate of wicking action of the filler, (3) the greater effective plastic absorbing surface due to the voids, and (4) the total absorption capacity of the filler itself.

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Metallurgy. *Alvin S. Cohan.* No. 33, Vocational and Professional Monographs Series. Bellman Publishing Company, Cambridge 38, Massachusetts. Rev. Ed., 1955. 32 pp. $1.00.

This monograph on metallurgy is typical of the more than seventy publications in this series,* which are designed to provide the essential information needed by a young person in considering a lifetime career. Each monograph is written by an authority in the field, and covers: history and development of the vocation; personal qualifications needed for entry; scholastic training needed; employment opportunities; remuneration; chances for advancement; advantages and disadvantages; bibliography and professional organizations.

These monographs contain more technical information than is found in most of the current literature on occupations, and are suited to the reading level of college rather than high school students. They are useful references for college or high school guidance workers. Bound in heavy paper covers, size 6 by 9 inches, the pamphlets average about 30 pages and retail at $1.00 each, with discounts to schools, colleges, and libraries.

*Other titles in this series which appeared in new or revised editions during 1955 were: *Astronomy, Dentistry, Dairy Industry, Soap and Detergent Industry,* and *Tool and Die Industry.*

MARJORIE HAMMOND.

The North American Midwest: A Regional Geography. *John H. Garland*, Ed. John Wiley & Sons, Inc., New York. 1955. viii+252 pp. College Edition, $6.75—Trade Edition, $8.00.

This is a competently written geography of the Midwest, mainly organized on an orthodox regional basis: an introductory chapter, followed by five chapters of systematic material, then ten chapters of regional material. In the regional sections, the Midwest is broken down into four inner and six outer regions, which in turn are broken down into smaller sub-regions. In most chapters, fragments of the natural-resources, facility, activity, institutional, and idea patterns are haphazardly arranged in encyclopedic-descriptive fashion (i.e., there is seldom an idea of hierarchy closely adhered to).

As usual in an edited volume, the quality of individual chapters varies widely. In the systematic sections, four chapters stand out. Chapter 1, The Heart of a Continent, does a creditable job of placing the Midwest in a national perspective. Chapter 4, Significance of Agriculture, and chapter 5, Structure of Industry, are both of high-quality descriptively and analytically. Chapter 6, Trade and Transportation, has more new material than any other chapter, and also gives the best national perspective of any chapter.

All ten of the regional chapters are strong on description, and short on disciplined structure. Chapter 7, The West-Central Lowland, and chapter 13, The Lower Ohio Valley, are especially interestingly portrayed. Chapter 10, The Upper Mississippi Valley, has a clear theme running through its presentation. Chapter 11, Upper Great Lakes, has the best hierarchial order of any regional chapter. All of the regional chapters have a wealth of interesting facts, but in most cases the organization of ideas does not lend itself to easy identification of the most important distinguishing characteristics or problems facing the region.

The volume ends abruptly, with no concluding chapter putting regional problems in a wider perspective of changing standards of living, changing material and social technology, changing demography, and changing natural-resources.

Little of this book is so interestingly written that a layman would take pleasure in reading it. Its wealth of factual background (well mapped but not photographed at all) certainly makes it a good college textbook. A classical portrayal of the Midwest still remains to be done (probably by a single gifted author rather than by a committee of competent specialists).

LAWRENCE A. HOFFMAN